MISSION SAFETY EVALUATION REPORT FOR STS-41

Postflight Edition: November 15, 1990

Safety Division

Office of Safety and Mission Quality

National Aeronautics and Space Administration

Washington, DC 20546

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EXECUTIVE SUMMARY

Space Shuttle *Discovery* lifted off from Kennedy Space Center (KSC) at 7:47 a.m. Eastern Daylight Time (EDT) on October 6, 1990. During the countdown, a short hold for weather and minor technical problems delayed the launch by 12 minutes beyond the 7:35 a.m. EDT launch window opening. The primary objective of the STS-41 mission was deployment of the Ulysses Spacecraft, which was successfully accomplished. Because a Radioisotope Thermoelectric Generator (RTG) is used to provide power for Ulysses, the launch was subject to White House approval; the approval letter was issued on September 21, 1990, by the Executive Office of the President, Office of Science and Technology Policy.

Ulysses and its booster stages were deployed from *Discovery's* payload bay at 1:48 p.m. EDT, at the beginning of the fifth orbit when the Shuttle was over the Pacific Ocean between Guam and Hawaii . The first of the two stages of the Ulysses Inertial Upper Stage (IUS) booster fired at 2:53 p.m. EDT, followed by the IUS second stage firing at 2:57 p.m. EDT. The Payload Assist Module (PAM-S) then ignited at 3:01 p.m. EDT; Ulysses separated from the PAM-S at 3:11 p.m. EDT. At PAM-S burnout, the geocentric velocity of Ulysses was 34,130 miles per hour, the fastest departure speed to date of any spacecraft leaving the Earth.

The two-stage IUS and the single-stage PAM-S boosted Ulysses on a trajectory that will take it to Jupiter in 16 months. A trajectory correction maneuver is planned for October 15-16, 1990, to fine-tune the Ulysses initial flightpath toward Jupiter. Following that operation, each of the spacecraft's 9 instruments will be turned on over a 6-1/2-week period. Upon arrival at Jupiter, the spacecraft will make some scientific studies of the giant planet and receive a gravity assist from Jupiter into a solar orbit almost perpendicular to the plane in which the planets orbit. Ulysses is scheduled to make its first observations of the sun's southern pole between June and October 1994 and continue on to observe the northern solar pole between June and September 1995.

On Flight Day 2, Ulysses deployed its radial boom, a 5.6-meter (18.2-foot) beam carrying a number of sensors for the spacecraft's science instruments. This slowed the spacecraft's spin rate from 6.8 revolutions per minute (rpm) to 4.7 rpm, as planned. As Ulysses flew toward Jupiter, the astronaut crew undertook their middeck experiments.

After a successful flight of slightly over 4 days, *Discovery* landed on orbit 66 on concrete runway 22 at Edwards Air Force Base at 9:57 a.m. EDT on October 10, 1990. Exterior inspection of *Discovery* found the vehicle in exceptionally clean condition; only a few minor dings to the tiles were found. *Discovery* tested new carbon brakes which may eventually allow the Space Shuttle to land at KSC. The initial assessment was that the brakes performed well, but no decision will be made until spring as to when Shuttles will land in Florida.

FOREWORD

The Mission Safety Evaluation (MSE) is a National Aeronautics and Space Administration (NASA) Headquarters Safety Division, Code QS produced document that is prepared for use by the NASA Associate Administrator, Office of Safety and Mission Quality (OSMQ), and the Space Shuttle Program Director prior to each Space Shuttle flight. The intent of the MSE is to document safety risk factors that represent a change, or potential change, to the risk baselined by the Program Requirements Control Board (PRCB) in the Space Shuttle Hazard Reports (HRs). Unresolved safety risk factors impacting the STS-41 flight were also documented prior to the STS-41 Flight Readiness Review (FRR) (FRR Edition) and prior to the STS-41 Launch Minus Two Day (L–2) Review (L–2 Edition). This final Postflight Edition evaluates performance against safety risk factors identified in the previous MSE editions for this mission.

The MSE is published on a mission-by-mission basis for use in the FRR and is updated for the L–2 Review. For tracking and archival purposes, the MSE is issued in final report format after each Space Shuttle flight.

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SECTION 1

INTRODUCTION

1.1 Purpose

The Mission Safety Evaluation (MSE) provides the Associate Administrator, Office of Safety and Mission Quality (OSMQ), and the Space Shuttle Program Director with the NASA Headquarters Safety Division position on changes, or potential changes, to the Program safety risk baseline approved in the formal Failure Modes and Effects Analysis/Critical Items List (FMEA/CIL) and Hazard Analysis process. While some changes to the baseline since the previous flight are included to highlight their significance in risk level change, the primary purpose is to ensure that changes which were too late to include in formal changes through the FMEA/CIL and Hazard Analysis process are documented along with the safety position, which includes the acceptance rationale.

1.2 Scope

This report addresses STS-41 safety risk factors that represent a change from previous flights, factors from previous flights that have impact on this flight, and factors that are unique to this flight.

Factors listed in the MSE are essentially limited to items that affect, or have the potential to affect, Space Shuttle safety risk factors and have been elevated to Level I for discussion or approval. These changes are derived from a variety of sources such as issues, concerns, problems, and anomalies. It is not the intent to attempt to scour lower level files for items dispositioned and closed at those levels and report them here; it is assumed that their significance is such that Level I discussion or approval is not appropriate for them. Items against which there is clearly no safety impact or potential concern will not be reported here, although items that were evaluated at some length and found not to be a concern will be reported as such. NASA Safety Reporting System (NSRS) issues are considered along with the other factors, but may not be specifically identified as such.

Data gathering is a continuous process. However, collating and focusing of MSE data for a specific mission begins prior to the mission Launch Site Flow Review (LSFR) and continues through the flight and return of the Orbiter to Kennedy Space Center (KSC). For archival purposes, the MSE is updated subsequent to the mission to add items identified too late for inclusion in the prelaunch report and to document performance of the anomalous systems for possible future use in safety evaluations.

1.3 Organization

The MSE is presented in eight sections as follows:

Section 1 - Provides brief introductory remarks, including purpose, scope, and organization.

Section 2 - Provides a brief mission description, including launch data, crew size, mission duration, launch and landing sites, and other mission- and payload-related information.

Section 3 - Contains a list of safety risk factors/issues, considered resolved or not a safety concern prior to STS-41 launch, that were impacted or repeated by anomalies reported for the STS-41 flight.

Section 4 - Contains a list of safety risk factors that were considered resolved for STS-41.

Section 5 - Contains a list of Inflight Anomalies (IFAs) that developed during the STS-31 mission, the previous Shuttle flight.

Section 6 - Contains a list of IFAs that developed during the STS-31 mission, the previous flight of the Orbiter Vehicle (OV-103).

Section 7 - Contains a list of IFAs that developed during the STS-41 mission. Those IFAs considered to represent a safety risk will be addressed in the MSE for the next Space Shuttle flight.

Section 8 - Contains background and historical data on the issues, problems, concerns, and anomalies addressed in Sections 3 through 7. This section is not normally provided as part of the MSE, but is available upon request. It contains (in notebook format) presentation data, white papers, and other documentation. These data were used to support the resolution rationale or retention of open status for each item discussed in the MSE.

Appendix A - Provides a list of acronyms used in this report.

SECTION 2

STS-41 MISSION SUMMARY

2.1 Summary Description of the STS-41 Mission

Space Shuttle *Discovery* lifted off from Kennedy Space Center (KSC) at 7:47 a.m. Eastern Daylight Time (EDT) on October 6, 1990. During the countdown, a short hold for weather and minor technical problems delayed the launch by 12 minutes beyond the 7:35 a.m. EDT launch window opening. The primary objective of the STS-41 mission was deployment of the Ulysses Spacecraft, which was successfully accomplished. Because a Radioisotope Thermoelectric Generator (RTG) is used on Ulysses to provide power, the launch was subject to White House approval; the approval letter was issued on September 21, 1990, by the Executive Office of the President, Office of Science and Technology Policy. (See Section 8 for a copy of the approval letter.)

During ascent, Flash Evaporator System (FES) primary "A" system shut down. The crew switched to the FES primary "B" system, which operated successfully. Once on orbit, FES "A" was activated and worked properly. It was believed that subcooling during ascent caused the FES "A" shutdown; past history has indicated occurrence of a similar problem.

Ulysses and its booster stages were deployed from *Discovery's* payload bay at 1:48 p.m. EDT, at the beginning of the fifth orbit when the Shuttle was over the Pacific Ocean between Guam and Hawaii . The first of the two stages of the Ulysses Inertial Upper Stage (IUS) booster fired at 2:53 p.m. EDT, followed by the IUS second stage firing at 2:57 p.m. EDT. The Payload Assist Module (PAM-S) then ignited at 3:01 p.m. EDT; Ulysses separated from the PAM-S at 3:11 p.m. EDT. At PAM-S burnout, the geocentric velocity of Ulysses was 34,130 miles per hour, the fastest departure speed to date of any spacecraft leaving the Earth.

The two-stage IUS and the single-stage PAM-S boosted Ulysses on a trajectory that will take it to Jupiter in 16 months. A trajectory correction maneuver is planned for October 15-16, 1990, to fine-tune the Ulysses initial flightpath toward Jupiter. Following that operation, each of the spacecraft's 9 instruments will be turned on over a 6-1/2-week period. Upon arrival at Jupiter, the spacecraft will make some scientific studies of the giant planet and receive a gravity assist from Jupiter into a solar orbit almost perpendicular to the plane in which the planets orbit. Ulysses is scheduled to make its first observations of the sun's southern pole between June and October 1994 and continue on to observe the northern solar pole between June and September 1995.

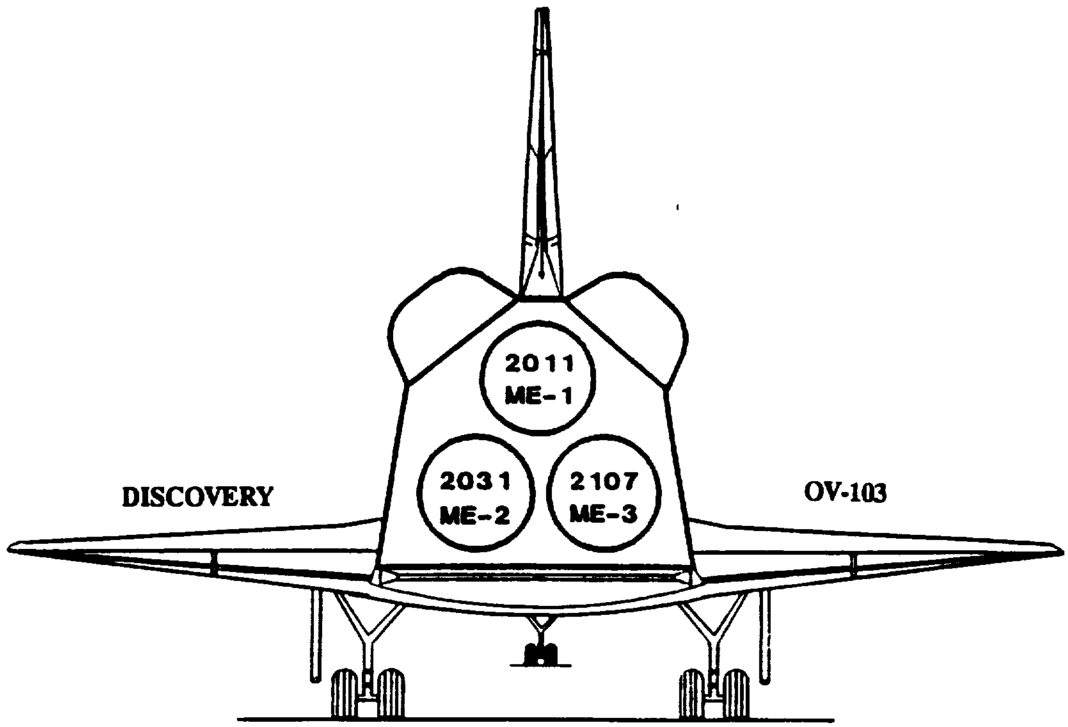
Downlink TV of the Ulysses deployment showed a shiny crescent-shaped object near the spacecraft. Initial evaluation of the object using the Closed Circuit Television (CCTV) camera and the crew camcorder indicated that the debris was a curved-shaped object approximately 21.6" long. Forward bulkhead camera views indicated that the object appeared behind the right Orbital Maneuvering System (OMS) pod near the vertical stabilizer. The origin of the object is still unknown. The object's size and shape does not correlate to any known item lost in the payload bay at KSC. The aft CCTV did not detect the object until after the IUS had cleared the payload bay. A similar piece of debris was observed on the STS-33 mission at payload bay door opening, originating from the aft end of the vehicle (not the payload bay). Marshall Space Flight Center (MSFC) and Boeing will conduct further analyses to attempt to identify the source of this debris.

On Flight Day 2, Ulysses deployed its radial boom, a 5.6-meter (18.2-foot) beam carrying a number of sensors for the spacecraft's science instruments. This slowed the spacecraft's spin rate from 6.8 revolutions per minute (rpm) to 4.7 rpm, as planned. As Ulysses flew toward Jupiter, the astronaut crew undertook their middeck experiments.

After a successful flight of slightly over 4 days, *Discovery* landed on orbit 66 on concrete runway 22 at Edwards Air Force Base at 9:57 a.m. EDT on October 10, 1990. Exterior inspection of *Discovery* found the vehicle in exceptionally clean condition; only a few minor dings to the tiles were found. *Discovery* tested new carbon brakes which may eventually allow the Space Shuttle to land at KSC. The initial assessment was that the brakes performed well, but no decision will be made until spring as to when Shuttles will land in Florida.

2.2 Flight/Vehicle Data

- Launch Date: October 6, 1990
- Launch Time: 7:47 a.m. EDT
- Launch Site: KSC Pad 39B
- RTLS: KSC Shuttle Landing Facility
- TAL Site: Banjul, The Gambia
- Alternate TAL Site: Ben Guerir, Morocco
- Landing Site: Edwards AFB, CA, Concrete Runway 22
- Landing Date: October 10, 1990
- Landing Time: 9:57 a.m. EDT
- Mission Duration: 4 Days, 2 Hours, 10 Minutes
- Crew Size: 5
- Inclination: 28.45 Degrees
- Altitude: 160 Nautical Miles Circular/Direct Insertion
- Orbiter: OV-103 (11) Discovery
- SSMEs: (1) #2011, (2) #2031, (3) #2107
- ET: ET-39
- SRBs: BI-040
- SRMs: RSRM Flight Set #14
- MLP: MLP #2



ENGINE	#2011	#2031	#2107
POWERHEAD	#2016	#2028	#2014
MCC*	#4005	#2019	#4002
NOZZLE	#4016	#4017	#4019
CONTROLLER	F24	F27	F25
FASCOS*	#17	#12	#29
HPFTP*	#5203R1	#4010R3	#6003R1
LPFTP*	#2030	#2120R1	#4007
HPOTP*	#2027R2	#2521R1	#2305R3
LPOTP*	#2126	#2120	#2216

* Acronyms can be found in Appendix A.

2.2.1 Partially Fixed Orifice Flow Control Valves

STS-41/OV-103 was the first Space Shuttle to fly with partially fixed orifice Gaseous Oxygen (GO_2) Flow Control Valves (FCVs). The current active GO_2 FCVs used in the External Tank (ET) Liquid Oxygen (LO_2) tank pressurization system will be replaced by Main Propulsion System (MPS) GO_2 fixed orifices. The GO_2 FCVs are used to return gas from the Main Engines back to the ET to maintain ullage pressure. The fixed orifice has been approved for Space Shuttle fleet implementation pending operational assessment and performance verification [Program Requirements Control Board Document (PRCBD) S50509R2]. Approval was based on results of the feasibility assessment performed by Space Shuttle Engineering/Level II and the supporting contributions of the MSFC ET Project. Incorporation of the fixed orifice hardware and procedures into the MPS eliminates some of the Criticality (Crit) 1 and 1R failure modes associated with the current FCVs which include the valves, the associated electronics, and the pressure-sensing transducers.

Flight tests with the FCVs shimmed for intermediate flow rates will be used to verify the analytical model and the final orifice size selection. The FCV stroke between high-flow and low-flow positions will be gradually changed over the course of 3 flights until the valves are fixed in one position. The ET GO_2 vent/relief valve pressure was increased from 24 pounds per square inch gage (psig) to 31 psig on STS-41 by replacing the spherical spring sensing assembly. This reduced the minimum ullage pressure from 16.0 psig to 14.2 psig, reducing 4 Crit 1R failure modes to Crit 3, and eliminating the effect of 15 other failure modes. The 31-psig GO_2 vent/relief valve was test qualified. The step #1 FCV orifice configuration was installed on STS-41/OV-103. These orifices were shimmed to 93% for high flow and 55% for low flow. The schedule leading to the implementation of fixed FCVs has been interrupted due to unavoidable shuffling of the Shuttle manifest. Final implementation of fixed orifices in GO_2 FCVs has not been scheduled.

2.2.2 First Flight for Redesigned Solid Rocket Motor Field Joint Protection System

STS-41 Solid Rocket Motors (SRMs) had the redesigned Field Joint Protection System (FJPS) on all field joints. This was the first flight for the redesigned FJPS. Original plans called for flying the redesigned FJPS on a field joint prior to full implementation on the STS-41 flight set. This was to occur on STS-38, which has the redesigned FJPS installed on 1 aft field joint; however, STS-38 was delayed until after STS-41. The FJPS redesign eliminates the need to install the moisture seal and vent valve, resulting in a reduction of installation time from 144 hours (hr) per joint to approximately 67 hr. This design also eliminates the need for use of extruded cork, a manufacturing savings.

The Space Shuttle System Safety Review Panel (SSRP) reviewed the redesigned FJPS and concluded that the design does not increase the risk of debris formation.

2.2.3 Software Upgrade for Orbiter Avionics and Space Shuttle Main Engine Controllers.

STS-41 was the first flight to use the new OI-8D software that was developed from the OI-8C base. Some of the areas in which capabilities were improved or added are Sequencing, Guidance and Navigation, Transatlantic Abort Landing, Systems Management, and Reconfiguration Data.

This was also the first flight of the AR01 upgraded Space Shuttle Main Engine (SSME) controller software. This upgrade adds monitoring capability to the controller software in preparation for the Block II controller. Capabilities not currently in the Block I controller have been inhibited. Verification testing of AR01 uncovered a problem with monitoring of the Pogo Precharge Pressure. This problem was fixed for STS-41.

2.2.4 External Tank Tanking Lightning Constraint

A change to the electrical storm activity constraint for ET tanking was in effect for STS-41. For the previous flight, STS-31, the requirement was verification that no more than a 20% probability existed for potential electrical activity within 5 miles of the launch pad during the first 4 hr of ET tanking. For STS-41 and subsequent missions, the first 4 hr of ET tanking condition is reduced to the first hr of ET tanking. This change was promulgated by Requirements Change Notice (RCN) S59684 and approved by the August 2, 1990, Program Requirements Control Board (PRCB).

The rationale for this change was:

- Present pad lightning protection is adequate:
  - Lightning masts (pad and ET)
  - Catenary system
  - Ground systems incorporate protection.
- Prediction accuracy improved for the first hr of tanking.

This change provides increased assurance that tanking can be accomplished effectively at KSC during summer months.

2.2.5 Contingency Return of Ulysses Results in Exceedance of Orbiter Downweight Restrictions.

The Orbiter is currently certified to vehicle downweights specified in VE3-90-006. There was the potential that a contingency return with Ulysses might be required. Returning with Ulysses placed the combined vehicle downweight at 235,000 pounds (lb); this is above the 230,000-lb limit. Rockwell performed an extensive analysis to determine the impact of a contingency return with Ulysses. The analysis indicated that there were no issues with flight performance and control, vehicle venting, or increased thermal loads. All increased loads were within certification limits and previous flight experience. There was, however, a requirement for a 155-minute thermal preconditioning prior to reentry. This requirement was planned into the STS-41 nominal end-of-mission attitude timeline. To protect the structural Factor of Safety (FOS) of 1.4, additional limits were imposed. A 1.98-g normal load limit around the heading alignment circle was specified to maintain the 1.4 FOS. Limits for touchdown sink speed were specified at 6.0 feet per second (fps) for no crosswind and 5.0 fps for crosswinds up to 20 knots. Exceeding these limits was not considered a safety-of-flight issue, because the resulting forces would yield and not fail Orbiter structural members. If Ulysses was returned and the loads were less than specified, a zonal (visual) inspection would have been required. If loads were determined to be greater than or equal to the above, a detailed inspection would have been necessary prior to the next OV-103 flight.

The results of the downweight analysis did not impact the planned landing site priority. STS-41 end-of-mission landing site priorities were as follows:

- Edwards AFB Concrete Runway
- Edwards AFB Lakebed
- KSC Concrete Runway
- Northrup

For Return-to-Launch Site (RTLS), the weight exceeded the 240,000-lb limit by approximately 970 lb. A waiver, PRCBD H42041M, was approved by Level I that allowed an RTLS abort downweight of 241,500 lb for STS-41 only. However, STS-41 was successfully launched, and Ulysses was successfully deployed. Therefore, Orbiter downweight was not a concern for STS-41.

2.2.6 Interruption of STS-41 Stacking Operations.

During the stacking of STS-41 boosters, the decision was made to roll the partially completed stack to Pad 39B to make room in the Vehicle Assembly Building (VAB) to roll back STS-35 after identification of a hydrogen leak. The Left-Hand (LH) booster, including the forward assembly, was completely stacked, and all joints had been closed out; however, stiffener ring splice plates had not been installed. The Right-Hand (RH) booster had been stacked only to the ET attach ring at the aft field joint. The remaining RH booster segments were either at the surge facility or on railcars awaiting offload. The partially complete STS-41 stack was at Pad 39B for approximately 9 days.

The partial RH stack was covered with various layers of protection. Lightning detectors were installed on each booster. While at Pad B, no unusual environmental conditions were recorded, and no lightning strikes were recorded on either of the 4 detectors installed. Inspection upon return to the VAB found no discrepancies or environmental damage. The STS-41 stack was cleared for flight.

2.2.7 Use of Lightweight Solid Rocket Motor Segments.

STS-41 was the first mission since STS-31 to use lightweight SRM segments. Deviation RDW-587R1 for the use of lightweight segments was approved through STS-31. This deviation was revised and approved at Level III as RDW-587R5 for the lightweight SRM segments assigned to STS-39, STS-40, and STS-41. SRM Hazard Report FC-02 will be updated to reflect the extension of this deviation. There was no increase to the risk baseline associated with this deviation.

2.3 Payload Data

Payload Bay:

- Ulysses – (See Section 2.4)

- Shuttle Solar Backscatter Ultraviolet (SSBUV) Experiment – The SSBUV payload is mounted in 2 Get-Away-Special containers. This experiment will help to fine-tune the atmospheric ozone measurements made by Advanced TIROS-N (ATN) satellites already in orbit by providing a calibration of their backscatter ultraviolet instruments.

- Intelsat Solar Array Coupon (ISAC) – Samples of solar array materials, mounted on *Discovery's* Remote Manipulator System (RMS), are designed to study the interaction of atomic oxygen wear on solar panels in preparation for a future Shuttle mission to rescue the stranded Intelsat satellite.

Middeck:

- Chromosome and Plant Cell Division in Space (CHROMEX) – A study of plant root growth patterns in microgravity.

- Voice Command System (VCS) – A development experiment in voice command of the Shuttle's onboard television cameras.

- Solid Surface Combustion Experiment (SSCE) – A study of flames in microgravity.

- Investigation into Polymer Membrane Processing (IPMP) – A study of materials processing in microgravity.

- Physiological System Experiment (PSE) – An investigation of how microgravity affects bone calcium, body mass, and immune cell function.

- Radiation Monitoring Equipment (RME)-III – Records radiation levels in orbit.

- Air Force Maui Optical Site (AMOS) – Technology development/geophysical environment study to calibrate AMOS ground-based electro-optical sensors and study on-orbit plume phenomenology using the Shuttle as a test object.

2.4 Ulysses Description

Space Shuttle STS-41/OV-103 deployed the Ulysses spacecraft on a 5-year journey to the sun. Ulysses is a joint mission conducted by the European Space Agency (ESA) and NASA to study the polar regions of the sun and the interplanetary space above the poles. The spacecraft will be the first to achieve a flightpath nearly perpendicular to the ecliptic, the plane in which Earth and the other planets orbit the sun. Throughout its 5-year mission, Ulysses will study three general areas of solar physics: the sun itself, the magnetic fields and streams of particles generated by the sun, and the interplanetary space above the sun.

The Ulysses spacecraft, a ground control computer system, and a spacecraft operations team were provided by ESA. The Space Shuttle launch, tracking, and data collection during the mission are performed by NASA and the Jet Propulsion Laboratory (JPL). Scientific instruments aboard the craft were provided by scientific teams in both Europe and the United States.

Communication with Earth is maintained via a 5.4-foot diameter, parabolic high-gain antenna. The spacecraft's telecommunications system includes two S-band receivers, two 5-watt S-band transmitters, two 20-watt X-band transmitters, the high-gain antenna, and two smaller low-gain antennas. The high-gain antenna is used to transmit in either S-band or X-band as well as to receive in S-band. The low-gain antennas are used both to transmit and receive in S-band. The spacecraft can transmit to Earth on 2293.148 Megahertz (MHz) in S-band or 8408.209 MHz in X-band.

The Ulysses power source is an RTG, similar to RTGs flown on previous solar system exploration missions. RTGs are required for these deep-space missions because solar arrays large enough to generate sufficient power so far from the sun would be too large and too heavy to be launched by available means. In the RTG, heat generated by the natural decay of plutonium-238 is converted into electricity by thermocouples.

Ulysses' scientific payload is composed of 9 instruments. In addition, the spacecraft radio will be used to conduct a pair of experiments over and above its function of communicating with Earth, bringing the total number of experiments to 11. Also, two other investigation teams will conduct interdisciplinary studies. The experiments are listed below.

- Magnetic fields
- Solar-wind plasma
- Solar-wind ion-composition spectrometer
- Heliospheric instrument for spectra, composition, and anisotropy at low energies
- Energetic-particle composition and neutral gas

- Cosmic and solar particle investigation
- Solar X-rays and cosmic gamma rays
- Unified radio and plasma-wave experiment
- Cosmic dust
- Coronal sounding
- Gravitational waves

In addition to the 11 experiments listed above, two investigation teams will study the following interdisciplinary topics.

- Directional discontinuities
- Mass loss and ion composition

Summary descriptions of these experiments are included in the background data referenced in Section 8. For more detailed descriptions of the Ulysses experiments, refer to Ulysses payload documentation.

SECTION 3

SAFETY RISK FACTORS/ISSUES IMPACTED BY STS-41 ANOMALIES

This section lists safety risk factors/issues, considered resolved (or not a safety concern) for STS-41 prior to launch (see Sections 4, 5, 6, and 7), that were repeated or related to anomalies that occurred during the STS-41 flight. The list indicates the section of this Mission Safety Evaluation (MSE) Report in which the item is addressed, the item designation (Element/Number) within that section, a description of the item, and brief comments concerning the anomalous condition that was reported.

ITEM		COMMENT
Section 4: Resolved STS-41 Safety Risk Factors		
SRM 2	STS-31 right Solid Rocket Motor (SRM) igniter adapter-to-forward dome joint putty blowhole.	Blowholes through the igniter outer joint putty was observed on both STS-41 SRMs (360Q013). The blowholes, sooting, and damage to the outer gasket seal retainer cadmium plating were similar to that seen on previous flight SRMs (including STS-31 and STS-36) and test motors. See Section 7, SRM 1 (IFA No. STS-41-M-01) for a detailed description of the damage incurred as a result of the putty blowholes on STS-41 SRMs. The increase in putty blowhole occurrences is believed to be related to the reduction in putty layup in the igniter joints. The reduction in putty was implemented to reduce the probability for putty to extrude into the joint sealing surface, as seen on STS-33. A redesign of the igniter-to-dome joint has been approved to delete joint putty. (IFA No. STS-41-M-01)

ITEM		COMMENT
Section 4: Resolved STS-41 Safety Risk Factors		
SRM 4	Aft dome factory joint internal insulation voids.	Abnormal erosion was found at the forward edge of the internal insulation on both SRM aft dome-to-stiffener and stiffener-to-stiffener factory joints on STS-41. However, postflight investigation determined that minimum erosion safety factors were met or exceeded in both areas. Verification was performed on all aft SRM segments using ultrasonic inspection techniques to verify insulation integrity. The concern was the effect that voids would have on maintaining the required 2.0 erosion safety factor in the aft dome factory joint insulation. Postfire insulation samples were taken from all SRMs. These samples had small, entrapped air voids. None of these were considered to be folds, bulges, or thin spots in the insulation. Voids have always been localized and are surrounded by rubber-tearing vulcanized bonds that do not propagate or communicate. Voids are in compression during motor operation. The minimum SRM insulation erosion safety factor over the aft dome joint has been determined to be 3.46 based on postfire evaluation of 400 insulation samples. It is relatively certain that all SRMs have had similar aft dome factory joint insulation voids. (See Section 7, SRM 2 for more details.) (IFA No. STS-41-M-02)

ITEM		COMMENT
Section 7: STS-41 Inflight Anomalies		
Integration 2	Aft compartment Hydrogen (H_2) concentration high during ascent. (IFA No. STS-41-I-03)	Postflight analysis of STS-41 aft compartment catch bottle contents indicated the highest ascent H_2 concentrations of any Shuttle mission. Leak rate calculations based on H_2 concentrations in the STS-41 catch bottles ranged from 25,000 standard cubic inches per minute (scim) to 37,000 scim. Average H_2 leakage during ascent for the fleet is less than 10,000 scim. Prior to STS-41, the maximum catch bottle H_2 concentration was on STS-31, the last OV-103 mission. Leak calculations based on the STS-31 sample resulted in an estimated leak rate of 30,000 scim. A leak greater than 59,000 scim, coupled with a sufficient amount of Oxygen (O_2), is considered to be the minimum flammability limit. Through the 11 OV-103 flights, there has been a trend of increasing H_2 concentrations in the catch bottles. At present, the cause of the leakage is unknown, and there were no indications of any leakage prior to launch. A possible leak source is the Space Shuttle Main Engines (SSMEs). Prior to engine start, only approximately 5% of the SSME H_2 joints are wetted. The 3 SSMEs on STS-41 have been on OV-103 for 3 flights, and all will be removed. Because of the potential for leakage, special tests, including bagging each SSME individually, will be performed. Additionally, all Main Propulsion System and SSME interface joints will be leak checked prior to SSME removal.

SECTION 4

RESOLVED STS-41 SAFETY RISK FACTORS

This section contains a summary of the safety risk factors that were considered resolved for STS-41. These items were reviewed by the NASA safety community. A description and information regarding problem resolution are provided for each safety risk factor. The safety position with respect to rationale for flight is based on findings resulting from System Safety Review Panel (SSRP), Prelaunch Assessment Review (PAR), and Program Requirements Control Board (PRCB) evaluations (or other special panel findings, etc.). It represents the safety assessment arrived at in accordance with actions taken, efforts conducted, and tests/retests and inspections performed to resolve each specific problem.

Hazard Report (HR) numbers associated with each risk factor in this section are listed beneath the risk factor title. Where there is no baselined HR associated with the risk factor, or if the associated HR has been eliminated, none is listed. Hazard closure classification, either Accepted Risk {AR} or Controlled {C}, is included for each HR listed.

The following risk factors contained in this section represent a low-to-moderate increase in risk above the Level I approved Hazard Baseline risk. The NASA safety community assessed the relative risk increase of each and determined that the associated increase was acceptable.

Integration 1	Difference between the Primary Avionics Software System and Backup Flight System could lead to recontact between the Orbiter and External Tank after separation.
Integration 2	Liquid Oxygen fill and drain valve closure in the event of power loss in terminal sequence.
Orbiter 1	OV-102 Engine Interface Unit Power-On Reset anomaly.
Orbiter 3	Auxiliary Power Unit Gas Generator Valve Module issue.
Orbiter 7	STS-41/OV-103 Freon Coolant Loop #1 leak.
Orbiter 11	OV-102 20-psi helium regulator leak.
Orbiter 12	Fuel Cell separator plate plating defects.

SECTION 4 INDEX

RESOLVED STS-41 SAFETY RISK FACTORS

SECTION 4 INDEX - CONTINUED

RESOLVED STS-41 SAFETY RISK FACTORS

RESOLVED STS-41 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>INTEGRATION</u>		
1	Difference between the Primary Avionics Software System (PASS) and Backup Flight System (BFS) could lead to recontact between the Orbiter and External Tank (ET) after separation. HR No. INTG-010 {AR} HR No. INTG-138 {C} ***No Orbiter/ET separation problems were experienced on STS-41.***	It was recently discovered that a difference exists between the PASS and BFS requirements which, under certain conditions, could lead to recontact of the Orbiter and ET at the forward attach point after separation. The PASS inhibits all rotational commands during the first 3 seconds (sec) of the ET separation maneuver; the BFS does not. In the case where the BFS is in control prior to the ET separation maneuver and a negative pitch rate command is issued as the -Z translation burn begins (ET separation maneuver), recontact is possible. The required pitch rate to overcome the -Z translation can be achieved by either 2 Reaction Control System (RCS) jets failing "on" after the negative pitch rate command is issued or by a transient induced by a Space Shuttle Main Engine (SSME) failure close to Main Engine Cutoff (MECO). The probability of either of these occurrences is extremely low. If a negative pitch rotational command is received as the -Z maneuver starts, the Orbiter nose will move toward the ET. The forward RCS would have no -Z jets firing, and recontact would occur at the forward strut. Damage on recontact would be minimal, if any, due to the slow closing rate. Positive pitch rate commands are not a problem, because the result would be to move the Orbiter away from the ET. It is planned to implement a fix in the BFS source code in the OI-21 build. Discussions among the technical community have concluded that implementation of a crew workaround procedure or software fix at this time would result in a higher risk than flying "as is". A crew user note was prepared cautioning against negative pitch commands during ET separation while in the BFS mode. Safety concurred with the assessment that there is a low probability of the required sequence of events occurring and agreed that nothing more should be done until OI-21 is available. A waiver was approved accepting this condition through STS-50, the first planned flight with OI-21.

RESOLVED STS-41 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
INTEGRATION		
1 (Continued)		Rationale for STS-41 flight was: • Low probability of occurrence. • If recontact should occur, damage would be minimal. ***This risk factor was acceptable for STS-41.***
2	Liquid Oxygen (LO_2) fill and drain valve closure in the event of power loss in terminal sequence. HR No. INTG-153 {C} ET P.02 {C} ***No prelaunch power fluctuation problems were experienced on STS-41.***	During STS-31 prelaunch activities, a failure in the Launch Complex 39 utility annex resulted in a momentary power fluctuation that caused the firing room launch sequence equipment to halt. The concern was that a similar power failure during the last 31 sec prior to launch would cause the firing room to lose control visibility. In the case of a subsequent on-pad abort, the firing room would be unable to control LO_2 fill and drain valves, resulting in the potential for geysering. A procedure was approved and implemented during the STS-31 launch countdown to ensure geyser suppression in the event of a similar failure during the terminal sequence. This procedure initiated transfer line leak purge at T–80 sec, and the crew would be instructed to open the LO_2 outboard and inboard fill and drain valves using onboard switches. During STS-31 terminal countdown, prerequisite control logic prevented the LO_2 outboard fill and drain valve from closing with the transfer line leak check purge activated, resulting in a momentary delay in the launch. Procedural changes were implemented for STS-41 to make sure that the prerequisite control logic was satisfied. Bypass of the outboard fill and drain valve control logic was performed at T-9 minutes (min). LO_2 transfer line leak check purge was initiated at T–80 sec. If power is lost to the firing room, verification

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
INTEGRATION		
2 (Continued)		that the Mobile Launch Platform (MLP) and the pad terminal connection room power lights are *on* is at the safing panel. Safing panels and critical Ground Support Equipment (GSE) are supported with batteries. The LOX Console Operator will configure the safing panels so that tank prepress is on, the main fill valve is open, and the ET vent is in the closed position. The NASA Test Director will instruct the crew to open the LO_2 outboard, and then inboard fill and drain valves from the Orbiter. After confirmation from the crew that switches have been thrown, the LOX Console Operator will activate the safing panel. Transfer line leak check purge will be deactivated, and the Tail Service Mast (TSM) vent and drain valves will go closed. LO_2 tank pressurization will be started, and the facility fill valve will go to the open position. LO_2 should then begin draining from the vehicle/ET. Approximately 2 min after power is restored, the LOX Console Operator can cycle the tank prepress with a switch to maintain nominal LO_2 drain pressures. The Launch Process Sequencer will regain control of the Launch Data Bus in 7 to 8 min after power is restored. Full firing room capability should be restored in 30 to 45 min. The NASA Test Director will execute a Mode 1 egress after switch action has been executed. Mode 1 egress is an unassisted emergency crew evacuation from the vehicle. Concerns have been raised relative to the crew/vehicle safety due to the hurried nature of a Mode 1 egress. Inadvertent switch/control activation may result if the crew is too hurried. Since the above procedure for geyser suppression should safely drain LO_2 from the vehicle/ET, egress timing is not as critical as it would be for other conditions. Crew evacuation from the pad has been questioned in this case. Mode 1 egress requires the use of emergency slides as the primary evacuation

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
INTEGRATION		
2 (Continued)		method. However, associated risk to the crew may be too great to warrant use of the slide wires. A decision was made to instruct the crew that a call for a Mode 1 egress in this case should be an orderly unhurried egress. Rationale for STS-41 flight was: • Procedures were developed to maintain control in the event of power loss during the terminal sequence. • Mode 1 egress will be initiated after crew sets appropriate switches. • Console operators and STS-41 crew were briefed on this scenario. ***This risk factor was acceptable for STS-41.***
3	Liquid Hydrogen (LH_2) leaks on STS-35/OV-102 and STS-38/OV-104. HR No. INTG-006A {AR} INTG-071 {AR} ORBI-306 {AR} ***No prelaunch LH_2 leakage problems were experienced on STS-41.***	Significant LH_2 leaks were experienced on STS-35/OV-102 and STS-38/OV-104. Extensive investigation of these leaks was conducted; a summary of associated activities can be found in the STS-35 MSE L-1 Day Edition, September 17, 1990. Preparations for STS-41 launch included additional measurements and inspections to define the condition of the mated ET and Orbiter LH_2 disconnect. Each side of the disconnect interface was examined and measured; no anomalies were reported. The primary and secondary interface seals were examined under 10-power magnification for contamination prior to installation. The Orbiter disconnect had flown previously. A new, 6000-series ET disconnect was installed on ET-39.

RESOLVED STS-41 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
INTEGRATION		
3 (Continued)		The ET disconnect 17" flange bolts were torqued to 660 inch-pound (in-lb). A tanking test was not performed on STS-41 prior to the launch attempt. The Launch Commit Criteria (LCC) for Orbiter/ET 17" umbilical Hydrogen (H_2) concentrations was also readdressed for STS-35 and was in effect for STS-41. After considering the results of the LH_2 leak investigation and extensive review of past and recent test data, the following LCC maximum redline requirements were established: • No presence of unusual vapors and liquid droplets. The term "unusual vapors and liquid droplets" is defined as: – An obvious blowing leak or a vapor cloud which obscures the disconnect or feedline region for an extended period (> 5 min). – Consistent frequent liquid drops falling or flowing with identifiable vapor trails. • No H_2 concentration greater than 40,000 parts per million (ppm) (4%) on both sensors [Leak Detectors (LDs) 54 and 55]. If a sensor has been declared failed, the remaining sensor must not exceed 40,000 ppm (4%).

RESOLVED STS-41 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>INTEGRATION</u> 3 (Continued)		• No H_2 concentration greater than 20,000 ppm (2%) on 1 of 2 sensors (LDs 54 and 55) without evaluation of available data by the Mission Management Team (MMT) and MMT approval to continue the launch countdown. • If intermittent or erratic readings occur, the data will be evaluated over a 10-min period to determine the actual H_2 concentration. The LCC for aft compartment H_2 concentration remained the same for STS-41/OV-103; 500 ppm maximum during fast fill and 300 ppm maximum during stable replenish. Safety concurred with this LCC for STS-41. Rationale for STS-41 flight was: • The ET 17" disconnect installed on ET-39 was new. No anomalies had been reported relative to the Orbiter disconnect. • LCC requirements will protect against launching with an excessive H_2 leak. ***This risk factor was acceptable for STS-41.***

RESOLVED STS-41 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>ORBITER</u>		
1	OV-102 Engine Interface Unit (EIU) Power-On Reset (POR) anomaly. HR No. INTG-165 {C} ORBI-066 {AR} ***No POR anomalies were reported on STS-41.***	During STS-35/OV-102 EIU testing, position 1, Serial Number (S/N) 23, the 60-Kilobit (Kbit) data path dropped out for 1.1 sec, and the subsequent reading of the Bite Status Register (BSR) indicated POR. The anomaly occurred once on April 27, 1990. The concern is that a simultaneous POR-A and POR-B in the last 30 sec prior to MECO will result in the General Purpose Computer (GPC) closing prevalves on running engines resulting in a catastrophic shutdown. (This is the worst-case failure scenario.) Failure of GPC command of the engine requires manual shutdown. Flight rules/crew procedures exist for this condition. System management alert and the Main Engine (ME) status (amber) light on the panel (F-7) will alert the crew. Crew reaction is required to manually shut down MEs prior to prevalve closure. The crew would require a ground call to confirm POR indication. The indication would reset after EIU recovery. This condition was briefed to the STS-41 crew prior to flight. After the third STS-35 launch attempt, 2 additional POR dropouts occurred, resulting in the removal and replacement of EIU S/N 23. The subject "Power-On Reset" is characteristic of previous occurrences (7 units, 9 vehicle flows since January 1983). POR was transient and self clearing, and troubleshooting did not reproduce the problem. Rationale for STS-41 flight was: • Each occurrence has been a single POR (POR-A or POR-B). • No single POR will fail more than one data command/data channel. • POR has not occurred in flight.

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
1 (Continued)		• A single POR prior to T–0 will result in a launch hold or launch abort (post SSME start). • Simultaneous reset of both channels has never been experienced and requires 2 failures. • The last 30 sec prior to MECO is a very short time window in which the crew cannot react, and flight rules and procedures exist for this condition. The probability for simultaneous failure of both POR-A and POR-B during this time is 7.9×10^{-12}. ***This risk factor was resolved for STS-41.***
2	Aluminum rivets installed in the wing assembly without proper heat treatment and corrosion protection. HR No. ORBI-277 {C} ***No problems associated with wing assembly rivets were reported on STS-41. Suspect aluminum rivets in the wing tip areas were replaced with steel pull-type rivets prior to launch.***	While removing the tape used to protect areas during tile work on OV-105 wings, the head of a 5/32" 2000-series rivet came off a clip that holds a Right-Hand (RH) wing tip stiffener. There was a concern that multiple rivet failures could lead to structural failure of the wing assembly. Scanning Electron Microscope (SEM) analysis of the failed rivet found that the failure was due to stress corrosion cracking near the rivet head. Stress corrosion is indicative of improper heat treatment; however, Alcoa Aluminum indicated that there is no reliable test to determine that the proper heat treatment was performed. Stress corrosion is also indicative of a corrosive environment and a high-tensile load. The greater concern was that this rivet failure was indicative of a generic problem, and other Orbiter wing assemblies could contain rivets that have a similar level of stress corrosion. To date, there has been only one other recorded rivet failure on a wing assembly. There have been

RESOLVED STS-41 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
2 (Continued)		24 additional rivet failures recorded in various applications. There are over 5 million 2000-series rivet application in the Orbiter fleet. Further details concerning this issue can be found in STS-35 MSE L-2 Edition, August 30, 1990, Section 4, Orbiter 11. For STS-41/OV-103, suspect aluminum rivets in the wing tip areas on both sides were replaced with steel pull-type rivets. This alleviated the potential for stress corrosion in the wing tip area. Rationale for STS-41 flight was: • Suspect aluminum rivets in the wing tip area were replaced. • There was no historical evidence of a generic 2000-series rivet problem. – Large areas of tile were removed from OV-102 during the post-Challenger down period; no similar rivet anomalies were discovered. – Several structural modifications were implemented in the fleet, including numerous rivet drill-outs, with no anomalies noted. ***This risk factor was resolved for STS-41.***

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
3	Auxiliary Power Unit (APU) Gas Generator Valve Module (GGVM) issue. HR No. ORBI-031 {AR} ORBI-184 {AR} *All APUs operated normally on STS-41.*	During the STS-31 launch attempt on April 10, 1990, APU #1 S/N 305 with GGVM S/N 3002 exhibited speed control problems shortly after startup (IFA No. STS-31-01). Failure analysis concluded that the speed control problem was caused by missing tungsten carbide material from the GGVM Pulse Control Valve (PCV) seat, allowing a fuel leak path. At the time, this failure mode was not considered generic (see Section 5, Orbiter 1 for further details). Recent testing and inspection of other GGVMs for this phenomenon found additional anomalies related to the valves. The resulting failure analyses concluded that the GGVM PCV and Shutoff Valve (SOV) failures were generic in nature. Conclusions drawn from the failure analysis indicated that PCV failures were related to high operating cycles; SOV failures were attributed to leaching of the valve seat. However, the most recent PCV failure on GGVM S/N 4003 indicated that PCV failure might not be cycle related as previously believed. Details of the GGVM investigation can be found in STS-41 MSE Flight Readiness Review (FRR) Edition, September 24, 1990, Section 4, Orbiter 3. The Orbiter Project Office (OPO) specified interim GGVM life limits to protect against the inability to shut down an APU. Discussion at the STS-35 ΔFRR, August 20, 1990, led to reevaluation of the life-limit requirements. GGVM life limits are now bounded by 25-1/2 months of SOV wet time and 72,000 PCV cycles. However, because of the recent PCV failure on GGVM S/N 4003, life limit based on PCV cycles may not be credible. In addition to the life-limit criteria, the OPO also specified a requirement for a liquid leak test on all APU/GGVMs prior to launch. This test verifies the integrity of the PCV seat. Passing the test provides some confidence that no PCV seat material is missing. Leak tests of STS-41/OV-103 APU/GGVMs were successfully performed at the pad.

RESOLVED STS-41 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
3 (Continued)		Rationale for STS-41 flight was: • STS-41/OV-103 APU/GGVMs did not exceed the life-limit criteria prior to launch. • Liquid leak tests were performed successfully, providing additional confidence that no pulse control seat material was missing. • LCC will not allow a launch with an APU in high speed. ***This risk factor was acceptable for STS-41.***
4	Wing struts below-minimum wall thickness. HR No. ORBI-277 {C} ***No problems attributed to wing strut tubes were reported on STS-41. The Ulysses payload and its associated booster stages were successfully deployed from the payload bay on the fifth orbit of OV-103. Therefore, the OV-103 landing weight was well below the certification limit.***	Numerous wing strut tubes in OV-103 and OV-104 were found with below-minimum wall thickness. The concern was that reduced strut wall thickness could lead to structural failure. Postflight inspection of OV-103 after STS-31 revealed a damaged strut tube in the Left-Hand (LH) wing. This strut was replaced. Failure analysis indicated that the buckled area occurred in a portion of the tube that had below-minimum wall thickness (0.012" instead of the required 0.018" minimum). Rockwell International (RI) analysis also concluded that the damage was not caused by flight loads, but most likely was work-related. There are 240 wing struts on each Orbiter wing. The tubing is purchased as seamless drawn 2024 aluminum with a 0.095" ± 10% wall thickness. The formed tube is chemically milled on the outer diameter to the specified wall thickness. The completed tube is ultrasonically inspected for wall thickness at 3 axial locations, 4 circumferential points per location.

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
4 (Continued)		RI ultrasonically measured wall thicknesses of all wing struts in OV-103 and OV-104 that have a margin of safety of 0.35 or less. OV-103 had 5 struts below the minimum in the LH wing and 10 in the RH wing. OV-104 had 2 in the LH wing and 2 in the RH wing. The worst below-minimum wall thickness condition was 0.006" that was found on the original strut. Other struts were 0.001-0.003" below the minimum. OV-103 and OV-104 struts were ultrasonically inspected at 8 circumferential locations at approximately mid-length. If they were not acceptable, both ends were also checked. Ultrasonic inspection was performed through a coating using a digital readout to give actual tube thickness. Individual tube thickness was not uniform. RI performed a stress analysis to determine the margin of safety, based upon design loads, for each strut in OV-103 that was undersized. If the struts having a margin of safety of 0.10 or less were assumed to be the worst-case condition found so far (i.e., 0.006" under the minimum), then their margins of safety were positive. The thin-wall areas were believed to be due to improper chemical milling. There was the potential of a contingency return with Ulysses. Returning with Ulysses would have placed the combined vehicle downweight at 235,000 pounds (lb); above the 230,000 lb limit. RI performed extensive analysis to determine the impact of a contingency return with Ulysses. Analysis determined that there were no issues with flight performance and control, vehicle venting, or increased thermal loads. All increased loads were within certification limits and previous flight experience. There was, however, a requirement for a 155-min thermal preconditioning prior to reentry. This requirement was already planned into the STS-41 nominal end-of-mission attitude timeline. To protect the structural Factor of Safety (FOS) of 1.4, additional

RESOLVED STS-41 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE

<u>ORBITER</u>

4 (Continued)

limits were imposed. For the heading alignment circle, a 1.98-g normal load limit around the heading alignment circle was specified. Limits for touchdown sink speed were specified at 6.0 feet per second (fps) for no crosswind and 5.0 fps for crosswinds up to 20 knots. Exceeding these limits was not considered a safety-of-flight issue because the resulting forces would yield and not fail Orbiter structural members. If Ulysses had returned and the loads were less than specified, a zonal (visual) inspection would have been required. If loads were determined to be greater than or equal to the above, a detailed inspection would have been required prior to the next OV-103 flight.

For Return-to-Launch Site (RTLS), the weight exceeded the 240,000-lb limit by approximately 970 lb. A waiver, PRCBD H42041M, was approved by Level I to allow an RTLS abort downweight of 241,500 lb for STS-41 only.

Rationale for STS-41 flight was:

- STS-41/OV-103 wing inspection identified the location of all undersized struts. Damaged struts were replaced. No further damage was noted.
- Detailed stress analysis verified a positive margin of safety on all tubes.
- All STS-41/OV-103 wing truss tubes were determined to be structurally acceptable for unrestricted use.
- Downweight analysis associated with Ulysses contingency return specified landing requirements to protect wing strut positive margin of safety.

This risk factor was acceptable for STS-41.

RESOLVED STS-41 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
5	Potential damage to RH Payload Bay Door (PLBD) resulting from the Orbiter Processing Facility (OPF) access bridge incident. HR No. ORBI-047A {AR} ORBI-056 {C} ***No anomalies attributed to the OPF access bridge incident were reported on STS-41.***	While OV-103 was in the OPF, the RH PLBD was damaged. Payload bay access bridges were in place, and the zero-gravity system was configured for PLBD operation with the weight basket pinned to the OPF structure. During movement of the aft bridge bucket, contact was made with the RH zero-gravity system, resulting in an inward/aft/upward load on the RH PLBD through the strongback. The bridge bucket operator was unaware that the zero-gravity system was hooked up to the RH PLBD. It was estimated that the PLBD deflected up to 31". Vehicle structural and mechanical inspections, including ultrasonic techniques, were performed by Kennedy Space Center (KSC) and RI/Tulsa personnel. Data analysis conducted by RI/Tulsa resulted in additional inspection of the interior frame webs and flanges at the inboard, aft strongback attach points. Minor delamination was discovered around 20 of 74 bolt holes . Delamination around 1 bolt pattern was repaired by injecting adhesive and installing 6 intermediate fasteners. The other 19 were dispositioned to fly "as is", with inspection required after STS-41. Minor elongation of 25 of 74 attach holes was also noted and dispositioned to fly "as is". The PLBDs were functionally tested; all components operated nominally. No structural or mechanical discrepancies were attributed to this incident. RI/Tulsa was directed to build a mathematical model to determine structural loads incurred during PLBD deflection. Results of this analysis indicated that the imposed load resulted in a 36% negative margin at frame X_o 895.3. Detailed inspection of this location was performed with no anomalies identified.

RESOLVED STS-41 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
5 (Continued)		Rationale for STS-41 flight was: • Extensive inspection of the RH PLBD and attach points found no evidence of cracks or debonds. • All identified bolt/hole anomalies were repaired or dispositioned to fly "as is". • Detailed inspection of the area with a calculated negative margin was completed, and it was cleared for flight. ***This risk factor was resolved for STS-41.***
6	Primary RCS L1A thruster leak. HR No. ORBI-305A {C} ***No RCS thruster anomalies were reported on STS-41.***	During STS-31, RCS thruster L3A failed "off"/leaked oxidizer on-orbit. Thruster L3A is located directly adjacent to L1A. At that time, the manifold valve was closed, and the manifold and L3A were evacuated. On return, thruster L3A was removed at Dryden, and feed lines were found plugged. The thruster mounting hole on the pod was not covered. No tile damage was noted at Dryden. During removal of the left pod at KSC, substantial tile damage was noted under L1A; 54 tiles were either loose or stained. All damaged tiles were replaced. Inspection of the ferry tail cone interior discovered oxidizer contamination. Confirmation was made that the RCS thruster heaters were properly configured for the ferry flight. Post-ferry flight tests verified that the heaters were operational. No further leakage of thruster L1A was noted after return to KSC.

RESOLVED STS-41 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>ORBITER</u>		
6 (Continued)		Analysis indicated that the tail cone allows dynamic, internal air flow adjacent to the thruster L1A valve assembly during ferry flight. Additionally, removal of thruster L3A left an opening for ambient air circulation around L1A. Ambient air flow at 15°F through the pod and tail cone made it impossible for the 30-watt L1A heater to maintain the required 60°F temperature. Thrusters can potentially leak at temperatures below 50°F. There was also evidence of thruster plug O-ring deterioration which confirmed that oxidizer leakage took place. Tile damage directly under thruster L1A was in a pattern expected for this leak scenario. Based on these findings, future thruster removals prior to ferry flight will have resulting openings covered to maintain required heating and minimize effects on adjacent thrusters. Rationale for STS-41 flight was: • Thruster L1A had not leaked since returning to KSC and was, therefore, determined to be ready-for-flight. • All damaged tiles were replaced. Tail cone damage was also repaired. ***This risk factor was resolved for STS-41.***

RESOLVED STS-41 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>ORBITER</u>		
7	STS-41/OV-103 Freon Coolant Loop (FCL) #1 leak. HR No. ORBI-275 {C} ORBI-300 {C} ORBI-321A {C} ***No further FCLs degradation was experienced on STS-41 beyond the 1% per day leak rate in FCL #1 that was known prior to launch. At the 1% per day leak rate, OV-103 could have remained in orbit for approximately 35 days.***	A leak was detected in FCL #1 on STS-41/OV-103 after going to the vertical position in the Vehicle Assembly Building (VAB). Prior to powerdown in the horizontal position, FCL #1 accumulator volumetric quantity was at 34.9%. When power was applied several days later after Orbiter/ET mate, FCL #1 quantity was determined to be 20.4%. The minimum freon quantity necessary to protect against freon pump cavitation is 18%. The freon charge decay rate was at or above the Operational Maintenance Requirements and Specifications Document (OMRSD) 0.5% per day leak rate limit. Decay rates stabilized at 1% per day in the vertical position. Leak checks at the pad isolated the freon leak to the ammonia boiler. Previous experience with freon leaks at the ammonia boiler on STS-2/OV-102 determined the leak cause to be galvanic corrosion of the ammonia boiler tubes. Corrective action for corrosion problems at that time was to change the ammonia boiler tubes to Austenitic 347 Stainless Steel. Tube braze procedures were also changed at that time to minimize grain growth. The problem on STS-41/OV-103 was the first instance of freon leaks through ammonia boiler tubes since these changes were implemented. Level I directed that a pressure test be performed to determine the size of the leak and whether the leak would grow under increased pressure. The pressure test was designed to increase FCL #1 freon pressure, in increments, to 1.25 times the Maximum Expected Operating Pressure (MEOP). The leak rate increased with pressure; however, it returned to pretest levels when pressure was removed. Monitoring of accumulator pressure after the pressure tests indicated little decay. The accumulator quantity degradation was reported to be less than 0.5% per day after the pressure test.

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
7 (Continued)		The consequence of a single FCL failure is a next primary landing site abort; the consequences of a failure of both FCLs is loss of vehicle and crew due to avionics equipment overheating during the reentry phase. Loss of the ammonia boiler during ascent results in potential inability to perform an Abort-Once-Around (AOA) and the inability to survive an 8-pounds per square inch (psi) hole-in-cabin emergency. Without the ammonia boiler, the Fuel Cells (FCs) may be damaged postlanding due to overheating. Based on the pressure test results, FCL #1 was topped off at 44% on September 27, 1990, and the plan was to fly "as is". Rationale for STS-41 flight was: • No further degradation in leak rate was expected. Leak rate/degradation rate was monitored until launch. • OMRSD/LCC prohibit launch with FCL #1 accumulator quantity below 18%. • Postlaunch degradation/loss of FCL #1 is covered by Flight Rules. ***This risk factor was acceptable for STS-41.***

RESOLVED STS-41 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
8	Main Propulsion System (MPS) joint weld issue. HR No. ORBI-306 {AR} ***No anomalies attributed to MPS joint weld problems were reported on STS-41.***	H_2 leaks on STS-35/OV-102 and STS-38/OV-104 raised concern for the potential of undetected weld defects in MPS joints. Undetected defects could lead to joint failure and potential leak paths. The majority of LH_2 MPS welds are inside vacuum jacketed lines and were not considered suspect. Because of weld defect concerns, a Johnson Space Center (JSC)/RI investigation was initiated. The investigation focused on non-vacuum jacketed lines, 2" diameter or less, that were manufactured by RI. X-ray records of 58 LH_2 and LO_2 welded MPS lines were reexamined. No out-of-specification conditions were found in 40 of the 58 lines. The remaining 18 were identified for further engineering evaluation. Fourteen lines were determined to be borderline interpretation cases and were accepted by engineering disposition. Detailed engineering evaluation was required on the x-rays of 4 others. Three of the 4 joints on OV-102 were: a Gaseous Hydrogen (GH_2) line, a Gaseous Oxygen (GOX)/LO_2 line, and an LO_2 bleed line; one line (a GH_2 line) is a spare. Conservative review of the x-ray images of the 4 joints led to the following interpretations: • The OV-102 GH_2 line showed a lack of weld penetration, approximately 0.030" long. • Lack of weld penetration, approximately 0.250" long, was found in the OV-102 GOX/LO_2 line.

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
8 (Continued)		• A crack-like indication, 0.055" in length, was found in the OV-102 LO_2 bleed line. • Lack of weld penetration in 60% of the circumference was identified in the spare GH_2 line. Given the above interpretations, fracture analysis was performed to determine the magnitude of the potential for flaw growth. A nominal flaw depth of 90% of 0.035" wall thickness was assumed. The analysis determined that flaw growth was not predicted for line exposures to proof-pressure tests and subsequent mission environments. Findings of the JSC/RI investigation did not identify generic concerns with welded MPS lines. Lines on STS-41/OV-103 were considered cleared for flight due to the similarity in the welding process and inspection criteria. Rationale for STS-41 flight was: • There was no indication of a generic problem. • Flaw growth was not predicted based on fracture analysis. ***This risk factor was resolved for STS-41.***

RESOLVED STS-41 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>ORBITER</u>		
9	LH ET umbilical door actuator anomalies. HR No. ORBI-302A {AR} ***No problems associated with the ET umbilical doors were reported on STS-41 after connector 50P881 was repaired prior to launch.***	During the STS-41 flow, anomalies were noted with the LH ET umbilical door electronics. Early in the flow, the LH ET door latch motor #2 latch-and-release indication failed. Troubleshooting found that fuse F5 in the aft motor control assembly #2 had blown. Continuity checks were performed on the circuit, and no shorts were found. Close inspection of all accessible wiring found no suspect areas. Flexing of wire bundles did not duplicate the problem. This anomaly was closed as unexplained, noting that the probable cause was an intermittent short in the wire harness or on an associated terminal board. During a recent aft compartment inspection, connector 50P881 on the LH ET door actuator was found damaged. The neutral wire to the drive motor was found broken. Conductors were exposed on the phase C drive motor line and on the ET door "closed indication" line. Retest of the connector determined that the "closed indication" line was open. Rework of this connector was completed. Subsequent testing was successful. No determination was made relative to how the connector was damaged. Rationale for STS-41 flight was: • Connector 50P881 was reworked and successfully passed required tests. ***This risk factor was resolved for STS-41.***

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
10	Cracks in APU dynatube fittings. HR No. ORBI-103 {AR} ***All APUs operated normally on STS-41.***	During Acceptance Testing Procedure (ATP) of APU S/N 307, helium-leak checks were performed. A 2 x 10^{-6} standard cubic centimeters per second (sccs) leak was found at the GGVM bypass dynatube fitting. The acceptance test allowable leak rate is 1 x 10^{-6} sccs. Dye penetrant inspection of the dynatube fitting identified a 90° circumferential crack. Inspection of the reference and inlet dynatubes found that 2 of 4 fittings also had cracks; 1 circumferential and several radial. All APUs at Sundstrand were inspected based on the S/N 307 findings. A dynatube fitting on APU S/N 310 was found with a 300° circumferential crack. No cracks were found on 2 other APUs, S/N 312 and S/N 207. GGVM dynatube fittings are made from 17-7 PH that is susceptible to stress corrosion. The presence of a contaminant is required to promote stress corrosion cracking. The stress corrosion problem was identified early in the program at the GGVM supplier. Dynatubes on improved APU GGVMs will be made from 17-4 PH. The APUs are helium-leak checked prior to and after acceptance testing, as well as after initial installation in the Orbiter. Critical flaws are considered screenable by these helium-leak checks. STS-41/OV-103 APUs had not experienced similar leaks during acceptance and post-installation testing. GGVM dynatube fittings were lockwired on installation.

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
10 (Continued)		Rationale for STS-41 flight was: • The APUs were helium-leak checked before and after the ATP. • The APUs were leak checked after initial installation in the vehicle. • No leakage was detected on OV-103 APUs, and there was no leakage history. • The design is failure tolerant; i.e. the dynatube fitting has a sealing surface outboard of the stress corrosion cracking area, and the fitting is lockwired in place. ***This risk factor was resolved for STS-41.***
11	OV-102 20-psi helium regulator leak. HR No. ORBI-306 {AR} ***No problems with the 20-psi helium regulators were reported on STS-41.***	During leak check activities following the first STS-35 launch attempt, one of the two 20-psi helium regulators was found to have a 1 x 10^{-4} sccs leak. The leaking regulator was removed after this finding and returned to the vendor for evaluation. This regulator was originally installed in OV-102 prior to its first flight and had experienced 9 missions. The 20-psi regulator fleet leader was on STS-41/OV-103 and had experienced 10 missions. Testing at the vendor identified an external helium leak greater than 18 standard cubic inches per minute (scim) at 285 psi. A leak of 2 scim was observed at the maximum system operating pressure of 30 psi; allowable leak rate at this pressure is

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
11 (Continued)		3 scim. Inspection and bubble leak checks identified 3 cracks in the sensor diaphragm. Wrinkles were also observed on the diaphragm. The diaphragm is constructed of 2 plies of 347 stainless steel, approximately 2 mils thick each. The sensor diaphragm is exposed to GH_2 sense line pressure. The diaphragm exerts forces on the Belleville springs that operate the regulator pilot poppet and regulate helium pressure. This was the first diaphragm failure in the program history. Materials and processing analysis at RI indicated that the diaphragm failed by fatigue cracking resulting from stress concentrations at the wrinkles. Possible causes of the wrinkles include reverse repressurization of the diaphragm and overstress during proof-pressure testing. Plastic deformation of the diaphragm is believed possible during proof-pressure testing. Because of this, the potential exists that all 20-psi regulator diaphragms are, as a minimum, wrinkled. Because one side of the diaphragm is exposed to GH_2, leaks through the diaphragm could lead to H_2 leakage into the aft compartment through the regulator ambient vent. Analysis indicated that a ruptured diaphragm could back-flow GH_2 at a maximum rate of 5000 scim. This potential leak is detectable by the aft compartment Hazardous Gas Detection System (HGDS) and would result in a scrub prior to launch. The regulator is used post-MECO to regulate the helium purge of the H_2 lines in the MPS. It is also used during reentry and landing to maintain positive pressure in the MPS lines and eliminates the potential for drawing in contamination. A helium isolation valve is upstream of the 20-psi regulator. The isolation valve could be closed if the regulator failed open.

RESOLVED STS-41 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
11 (Continued)		Rationale for STS-41 flight was: • This was the first diaphragm failure in the program history. • OV-103 20-psi regulators were verified by helium signature leak checks and functional tests. o If GH_2 leaks through the diaphragm after launch, maximum leak rates result in below-allowable aft compartment H_2 concentrations and flammability limits. ***This risk factor was acceptable for STS-41.***
12	FC separator plate plating defects. HR No. ORBI-282A {C} ***All FCs operated normally on STS-41.***	During recent refurbishment of FC S/N 109, plating blisters were found on 6 separator plates. These blisters were similar to those observed on separator plates from S/N 104 and S/N 115 in September 1989, which led to an indepth investigation. That investigation determined that all suspect separator plates were from the same manufacturing lot. The blistered separator plates found in S/N 109 were not from this suspect lot and, therefore, gave rise to the potential for a generic problem with all FC separator plates. Investigation of the S/N 109 plates is in process. Two of the 6 plates have been examined to date; no active corrosion was found. The previous investigation found that the blister failure mechanism was separation of the gold and nickel layers from

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
12 (Continued)		the magnesium base material. At that time, no corrosion was observed through to the magnesium base. Potassium hydroxide, used as an electrolyte with water, was determined to passivate the bare magnesium so that corrosion could not occur. Corrosion pits could potentially develop, however, if material impurities are present at the blister site. The concern associated with blistering is based on the potential for explosive mixing of H_2 and Oxygen (O_2) through the separator plates, resulting in loss of the vehicle and crew. Indication of H_2 and O_2 mixing requires immediate FC shutdown and safing. Leakage in the H_2-to-O_2 separator plate can be detected by the FC performance monitor. If leakage is detected, procedures call for the crew to shut down the indicated FC. Loss of 1 FC results in a minimum-duration flight; loss of a second FC requires emergency powerdown and landing at the next primary landing site. Mixing of H_2 and coolant is more benign, resulting in slow degradation in FC performance. Turnaround testing also checks for potential leakage through the use of Nitrogen (N_2) diagnostics and coolant leak checks to verify FC integrity. All STS-41/OV-103 FCs passed these tests. Preliminary assessment indicated that STS-41/OV-103 FCs contained separator plates that were suspect. FC #1, S/N 114, had 1 H_2-to-O_2 suspect plate and no H_2-to-coolant plates. FC #2, S/N 103, had no suspect plates. FC #3, S/N 119, had 14 suspect H_2-to-O_2 plates and 6 suspect H_2-to-coolant plates. Both FC #1 and FC #3 were installed prior to STS-31 and had 191 hours (hr) and 196 hr total operating time, respectively. FC #2 was installed after STS-31 and had no accumulated operating time.

RESOLVED STS-41 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
12 (Continued)		FCs used for the qualification test program operated for 2000 hr with no problems. A historical review found that FCs have successfully operated with blistered plates for up to 3500 hr. FCs S/N 104 and S/N 115, where blisters were initially found, had over 1000 hr of operating time. FC S/N 109 had 411 hr of operation prior to the refurbishment effort that identified the 6 blistered plates. STS-41/OV-103 FCs had less than 200 hr of total operation. Investigation is ongoing to determine a solution to the blister failure mode. Turnaround testing and inflight FC performance monitoring will continue to be the mitigating control against catastrophic H_2-to-O_2 separator plate leakage until a solution is found. Rationale for STS-41 flight was: • No corrosion was detected during failure analysis of all blistered separator plates. • Leakage is detectable by existing instrumentation monitored in the Mission Control Center (MCC); a detected problem in flight results in a ground call for the crew to shut down and safe the problem FC. • Turnaround testing was completed with no identified problems. • STS-41/OV-103 FCs had very low operating time. FCs #1 and #3 flew on STS-31 with no identified performance degradation. ***This risk factor was acceptable for STS-41.***

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>SSME</u>		
1	High-Pressure Oxidizer Turbopump (HPOTP) bearing etching/corrosion issue. HR No. ME-C1 (All Phases) {AR} ME-C2 (All Phases) {AR} ***No HPOTP problems were experienced on STS-41.***	HPOTP bearing radial faces are electrochemically etched with a lot serial number during manufacturing. The etched serial number should be removed prior to final assembly in accordance with applicable drawings. It was determined, however, that an inspector misinterpreted the drawing requirements and allowed etched bearings to be installed. A total of 107 bearings were identified as having been processed through this inspector. Forty of the 107 bearings were designated as turbine-end bearings; 30 of these had been inspected, with 2 etched and 28 unetched. The remaining 67 were designated as pump-end bearings; 39 had been inspected with 21 etched and 18 unetched. Only 5 suspect bearings were identified as installed on pumps. There were 2 each in HPOTPs on engines #2031 and #2026 at the KSC engine shop. There were 2 suspect bearing faces on HPOTP #2521R1 on engine #2031, ME #2 on STS-41/OV-103. There were 2 other suspect bearings on the HPOTP on engine #2026 and 1 other on engine #2031. Material analysis of an etched bearing was performed to determine the worst-case effects. Dissection found that the average etch depth was 0.0002", with the deepest at 0.0005". Stress analysis indicated that an etch depth of 0.001", less than the critical flaw size, could be tolerated with an adequate margin of safety. Bearing hardness in the etched area was measured to be within specification. No intergranular attack was present; however, traces of chloride contamination were found in the etched area. Chloride contamination is of concern because it can lead to stress corrosion problems. Stress corrosion induced by chloride contamination led to the elimination of a chilling process previously used in the bearing assembly process. Bearings are now installed using a new drying process. All HPOTP bearings on STS-41/OV-103 engines were installed using this new process.

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
SSME		
1 (Continued)		The investigation performed by the SSME Project and Rocketdyne determined that HPOTP #2521R1 on STS-41/OV-103 engine #2031 was acceptable for flight with the suspect bearings installed. This determination was based on an inspection of HPOTP #2522R1, which had a similar etched bearing installation and operating condition as HPOTP #2521R1. No corrosion, pitting, or cracking was found on HPOTP #2522R1. HPOTP #2521R1 will be torn down and inspected following STS-41. Rationale for STS-41 flight was: • Electrochemical etch was much less than the critical flaw size. The FOS was greater than 2.0 for the critical flaw size. • The new drying procedure was used to ensure absence of moisture that can lead to stress corrosion. • A similar HPOTP was determined to have no corrosion, pitting, or cracking. ***This risk factor was resolved for STS-41.***

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
SSME		
2	Rigid fuel bleed duct stress corrosion cracking, engine #2029. HR No. ME-D3 (All Phases) {AR} ***No problems associated with fuel bleed ducts were reported on STS-41.***	A leak was detected at the rigid fuel bleed duct insulation expansion joints during engine #2029 post-acceptance test leak checks. The leak was isolated to a 0.1" long stress corrosion crack. Contamination embedded in the crack near the outer surface was determined to be grinding wheel constituents (silicon, calcium, and sulfur). There was a second stress corrosion crack found adjacent to the first, measuring 0.020" long and having similar contamination. There was no evidence of fatigue propagation in the through crack. The outer surface of the rigid fuel bleed duct showed signs of mechanical polishing and etching. There was no other corrosion or cracks found in the duct. Engine #2029 rigid fuel bleed duct was initially fabricated in April 1982. At that time, there were no corrosion inhibitor requirements for the duct. Stress corrosion cracking found in a low-pressure fuel duct in 1985 led to a requirement for duct inspection and the application of corrosion inhibitors to all insulated 21-6-9 Corrosion Resistant Steel (CRES) ducts. This requirement became effective in 1989 with STS-28 engine ducts. Engine #2029 rigid fuel bleed duct was refurbished in March 1988. At that time, a visual and dye penetrant inspection found corrosion pitting near the duct mount bracket, near the location of the recent leak. Analysis of surface replicas revealed a stress corrosion crack at one pit and recommended sanding and further inspection. Material review disposition specified blending to remove pitting and etching, penetrant inspection, and verification of duct wall thickness (> 0.027"). Stress corrosion was not specifically addressed in this disposition, and no leak check was required. It was concluded that the stress corrosion crack and leak path existed during the March 1988 refurbishment. The leak resulted from a 0.10" long stress corrosion crack with intermittent corrosion. An adjacent partly-through 0.20" long corrosion crack was similarly contaminated.

RESOLVED STS-41 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>SSME</u>		
2 (Continued)		No other corrosion or cracks were found in the duct. Contamination induced by the blending process (silicon, calcium, and sulfur grinding wheel constituents) prevented discovery of the stress corrosion crack during subsequent inspections. Engine #2029 flew on STS-30 and STS-34, and it is believed that the leak was either too small for detection or was contained by the duct insulation. The finding of this refurbishment discrepancy led to the review of all flight duct material review dispositions that identified corrosion. Six flight units were dispositioned for rework due to corrosion similar to that on the engine #2029 rigid fuel bleed duct. Three have been identified on STS-41/OV-103 engines: a low-pressure fuel duct and rigid fuel bleed duct on engine #2031, and a low-pressure fuel duct on engine #2107. Only the rigid fuel bleed duct on engine #2031 was determined to be unacceptable for flight; it was replaced. No corrosion was identified during refurbishment of the replacement duct. Low-pressure fuel ducts on engines #2031 and #2107 were leak tested and found acceptable. Rationale for STS-41 flight was: • All STS-41/OV-103 insulated 21-6-9 CRES ducts were inspected for corrosion and refurbished with corrosion inhibitor. • Engine #2031 rigid fuel bleed duct was replaced. No corrosion was identified during refurbishment of the replacement unit. • All engines passed the helium signature test (insulation closeout was removed from low-pressure fuel ducts on engines #2031 and 2107). ***This risk factor was resolved for STS-41.***

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
SSME		
3	High-pressure fuel duct flange radius cracking. HR No. ME-D3 (All Phases) {AR} ***No problems associated with high-pressure fuel ducts were reported on STS-41.***	OMRSD requirements direct preflight and postflight dye penetrant examination to determine if high-pressure fuel duct flange cracking exists. Preflight examination must occur within 45 days of flight. The 45-day interval is based on maximum sustained crack growth for 90 days and engine testing with cracked ducts. Crack propagation has not been demonstrated during hot-fire testing of 4 high-pressure fuel ducts with flange cracks. Ducts with cracks identified during the preflight dye penetrant examination are removed prior to flight. During OMRSD dye penetrant examination of STS-41/OV-103 engines, numerous cracks were discovered on engine #2031 high-pressure fuel duct flanges. One crack was 0.030" long; this was longer than typically seen. Because of this discovery, the high-pressure fuel duct was replaced. The high-pressure fuel ducts on engines #2011 and #2107 passed dye penetrant inspection and were cleared for flight. Sustained load cracking in the high-pressure fuel duct flange fillet radii was first identified in 1986. There are 2 flanges on the duct: at the F-4 joint, the interface between the duct and the HPFTP, and at the F-5 joint between the duct and the main fuel valve interface. The basic cracking mechanism was attributed to hydride formation from hydrogen diffusion within the basic 5AI-2.5Sn titanium material in regions of high-sustained tensile stress. Sustained tensile stress was reduced by lowering the preload at each joint. Recently, cracks were found in a high-pressure fuel duct flange that had been installed with lower preload. These cracks were found during post-proof test inspection after the duct insulation system had been repaired.

RESOLVED STS-41 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>SSME</u> 3 (Continued)		Evaluation of the cracked duct determined that crack formation at the flange was consistent with that associated with high-sustained tensile stress. There were numerous initiation sites within the flange fillet radii. Most cracks were 0.010" long; however, some cracks joined in a stair-step pattern to a length of 0.025". No machining tears or anomalous surface conditions were identified. Rationale for STS-41 flight was: • All high-pressure fuel duct flanges on STS-41/OV-103 SSMEs were examined using the dye penetrant technique. Two of the 3 passed this examination. The failed duct on engine #2031 was replaced. • The 45-day dye penetrant examination is adequate to detect cracks that could affect flange preload or duct performance. • If undetected cracks exist, no adverse affects are anticipated based on hot-fire tests with cracked duct flanges. ***This risk factor was acceptable for STS-41.***

RESOLVED STS-41 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>SRB</u>		
1	Hydraulic system Quick Disconnect (QD) spring anomalies. HR No. A-20-04 Rev. C-DCN3 {C} B-20-09 Rev. C-DCN3 {C} *No problems associated with hydraulic system QDs were reported on STS-41.*	During visual inspection of a 3/4" QD spring sealing surface prior to installation, a crack was observed. This QD, S/N 1000120, had flown once on STS-34; it had been disassembled, inspected, and reassembled; and had passed ATP prior to the discovery of the cracked spring. The spring is an electropolished PH 17-7 CH900, compression-type spring with ends closed and ground. This was the first observed crack of PH 17-7 springs in the history of the Solid Rocket Booster (SRB) program. The crack emanated from a machined notch on the first coil at the trailing edge of the ground end. There was also a notch on the last coil. These notches resulted from the finish grinding operation. Inspection revealed notches on other springs. Clamping marks were also found at other positions on various springs. Approximately 32 of the 54 3/4" springs inspected had indications of notches and clamp marks. Metallographic analysis of the spring crack indicated the potential for formation of small particles and flakes. These particles and flakes could be released from the cracked surface and become contamination in the SRB hydraulic system. If a flake was released from the high-pressure fill QD, it could migrate to the hydraulic reservoir bootstrap cylinder and become trapped between the cylinder and wall. This could result in internal leakage; however, no hydraulic system performance degradation would result. A loose flake emanating from the low-pressure QD could migrate to the hydraulic reservoir low-pressure side and into the hydraulic pump. This condition would result in minor degradation of hydraulic pump operation, but the pump would stay within operating parameters.

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>SRB</u> 1 (Continued)		Materials and processing testing and analysis were performed in an effort to create a crack in a spring and to understand the failure mode. Testing included sustained load testing, cyclic load testing, elevated temperature salt water bath, and hydrogen sulfide environmental testing. Only the hydrogen sulfide environmental test created a failure. PH 17-7 cracking in a laboratory hydrogen sulfide environment was expected; it is a known phenomena. The most probable introduction of H_2 into QDs prior to delivery to United Space Boosters, Inc. (USBI) is chemical descaling of the spring prior to electropolish using a solution of nitric acid only as a backup method. There are no processing steps that introduce H_2 in the refurbishment processing evaluation. There are no operations or interactions in flight systems processing that will introduce H_2 into QDs. A review determined that 1/4" QDs used in the SRB hydraulic fuel system were similar in design and manufacturing process. Inspection of 116 1/4" QD springs found no indication of notches or cracks. Based on finding unacceptable 3/4" QD springs, all eight 3/4" QDs on STS-41 SRBs were removed and replaced. Notches were found on 4 of the 8 springs. No cracks were found on any removed QD spring; therefore, no contamination resulting from associated flaking was considered present in the STS-41 SRB hydraulic systems.

RESOLVED STS-41 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>SRB</u>		
1 (Continued)		Rationale for STS-41 flight was: • All suspect QD springs were removed from STS-41 SRBs and replaced. There were no notches or cracks in the replacement springs. • No contamination was evident, based on not finding cracked springs. • SRB hydraulic system performance would not be degraded if this type of contamination is present. • Review of 116 1/4" springs revealed no notches or cracks. ***This risk factor was resolved for STS-41.***
2	Hydraulic fluid spill in the LH SRB aft skirt. HR No. A-20-04 Rev. C-DCN3 {C} B-20-09 Rev. C-DCN3 {C} ***No problems attributed to the hydraulic fluid spill were reported on STS-41.***	During hydraulic closeout of the LH SRB aft skirt, it was discovered that hydraulic fluid had leaked down the aft skirt. The leak was located near the rock actuator between Holddown Posts (HDPs) #6 and #7 on the interior of the aft skirt. The aft skirt instafoam and the thermal socks covering the APU turbine exhaust ducts were also exposed to the leaking hydraulic fluid; SRB thermal curtains were not exposed. The leak was estimated at approximately 20 gallons. Troubleshooting determined that the leak emanated from a GSE QD. Examination of the QD O-ring found missing O-ring material approximately 1/2" long.

RESOLVED STS-41 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
SRB 2 (Continued)		There was some concern that missing O-ring material might be inside the SRB Thrust Vector Control (TVC) system; however, the majority of the hydraulic system is protected against contamination with a 5-micron filter. The high-pressure relief valve does have the potential for exposure to O-ring contamination. In this case, there is a potential for a particle to prevent the relief valve from reseating if the valve was opened due to system overpressure. Loss of the TVC system due to contamination requires 3 failures: hydraulic system overpressure, causing the relief valve to open; O-ring particle restriction of relief valve seating; and failure of the tilt TVC system. Hydraulic fluid from the LH SRB system was sampled and tested for contamination prior to launch. Instafoam exposed to hydraulic fluid poses a potential flammability concern as well as a concern for degradation of thermal protection capabilities. USBI has tested instafoam exposed to hydraulic fluid for up to 5 hr. Post-test examination found no detectable degradation of instafoam capabilities. For STS-41, untrimmed areas of instafoam were wiped clean of hydraulic fluid, and trimmed areas were cut away. In addition to these actions, the turbine exhaust duct thermal socks were removed and replaced. Rationale for the STS-41 flight was: • Cleanup of spilled hydraulic fluid was completed prior to launch. • Turbine exhaust duct thermal socks were replaced.

RESOLVED STS-41 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>SRB</u>		
2 (Continued)		• Limited exposure of instafoam to hydraulic fluid results in no detectable degradation. • Contamination in the hydraulic system is controlled by a 5-micron filter. • Three independent failures are required for loss of the TVC. ***This risk factor was resolved for STS-41.***

RESOLVED STS-41 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>SRM</u>		
1	Putty on igniter inner gasket of test motors. HR No. BC-02 Rev. B {AR} BC-03 Rev. B {C} BI-02 Rev. B {C} ***No putty was found on the STS-41 igniter gaskets.***	Putty was found on the igniter inner gasket of Test Evaluation Motors (TEM)-5 and TEM-6 at the postfire inspection. The putty could impair gasket resiliency and allow blowby. The putty could also mask a leak during a leak test, thereby preventing the detection of a potentially defective gasket assembly. The LCC was raised to 100°F at T–9 min to guarantee a seal temperature of 95°F at T–0. The igniter heater setpoint was raised from 95°F ± 1°F to 110° ± 1°F. (For more information, see STS-31 MSE L-1 Update Edition, April 23, 1990, Section 4, SRM 4. Rationale for STS-41 flight was: • The recommended LCC of 100°F and igniter heater setpoint of 110°F provide the required tracking factor with a potential TEM-5/TEM-6 type condition for the STS-41 as-built condition. The required tracking factor of 1.4 is met, and the tracking factor is greater than 1.0 for the highly unlikely condition of putty in 3 of the 4 grooves in the seal. • Tests with putty in the gasket showed that the bolt preload is not affected, an overfill condition is not created, and the seal crown footprint is unaffected. • The design is safe because redundant seals exist and function as designed (10 tests; SRM, DM-6, TPTA, JES, and NJES experience), STS-41 leak tests were normal and within the data base, and the gap closes after the igniter operation (0.55 sec). ***This risk factor was acceptable for STS-41.***

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
SRM		
2	STS-31 right Solid Rocket Motor (SRM) igniter adapter-to-forward dome joint putty blowhole. HR No. BC-02 Rev. B {AR} BC-03 Rev. B {C} ***Blowholes through the igniter outer joint putty was observed on both STS-41 SRMs (360Q013). The blowholes, sooting, and damage to the outer gasket seal retainer cadmium plating were similar to that seen on previous flight SRMs (including STS-31 and STS-36) and test motors. See Section 7, SRM 1 (IFA No. STS-41-M-01) for a detailed description of the damage incurred as a result of the putty blowholes on STS-41 SRMs.***	A blowhole was found in the STS-31 right SRM adapter-to-forward dome (outer) joint putty at 180°, with no soot past the seals. Soot was noted on the outer gasket retainer Inside Diameter (ID) edge from 117° through 0° to 18°. Soot was also found on the inner igniter gasket retainer Outside Diameter (OD) edge and aft face of the full circumference. The cadmium plating was corroded from 155° to 220°, with the majority of the corrosion between 175° and 185° on the igniter inner gasket retainer aft face and OD edge. Minor pitting with a maximum depth of 2 mils was also observed at the above location. A blowhole was also found on the STS-31 left SRM. A blowhole and pitting were observed on the STS-36 right SRM igniter/forward dome boss interface (IFA STS-36-M-01). (See Section 5, SRM 1, STS-31 MSE L-1 Update Edition, April 23, 1990.) A redesign effort on the igniter-to-dome joint is in work to delete the joint putty. An investigation team is working on changing the gasket retainer material from cadmium-plated steel to stainless steel. A Level II action item is pending for the SRM Project Office to review a design change to remove cadmium plating from the Gask-O-Seal. Rationale for STS-41 flight was: • Blowholes through the igniter joint putty have been witnessed on the majority of flight and test SRMs, with no damage to the sealing capability of the joint (no evidence of blowby or damage of the elastomer and no damage to structural components).

RESOLVED STS-41 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>SRM</u>		
2 (Continued)		• Worst-case blowhole of 0.1" would result in no damage to the elastomer seal. • Worst-case analysis predicted positive structural margins of safety. • There is no known mechanism that would lead to hot-gas circulation in the igniter joint. ***This risk factor was acceptable for STS-41.***
3	Debris in the SRM nozzle flex bearing cavity. HR No. BN-06 Rev. B DCN64 {AR} ***No problems attributed to flex bearings were reported on STS-41.***	Recent inspections of 3 flight SRM sets found an extensive amount of foreign material in the nozzle flex bearing cavity. The concern with this foreign material was the possibility of interference with the nozzle TVC functions and potential fire hazard. Following is a summary of the foreign material found: • A dry-fit bolt from nozzle internal joint #4 was found on STS-35. The bolt size was 1.5" long x 0.5" diameter with a 0.75" diameter head (removed). • "Bubble" wrap packing material and a 3" x 5" squeegee were found between the snubber and nozzle aft end ring on STS-40. • Small pieces of masking tape, a small square of "bubble" wrap, and a cotton swab were found on STS-39.

RESOLVED STS-41 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
SRM		
3 (Continued)		Discovery of the dry-fit bolt in the STS-35 SRM nozzle joint caused the most concern of all the foreign material found. Analysis determined that the worst-case scenario occurs when the bolt becomes lodged between the nozzle snubber and the aft end ring. In this case, the bearing rubber would compensate to some unknown extent for the restriction; however, a possible new nozzle pivot point could be established. Structural assessment of this scenario indicated that the worst-case loading incurred by the lodged bolt could stall the nozzle actuator. If this occurred, it was anticipated that the failure mode would be local yielding of the snubber support ring with additional damage probable to the snubber segment. In the case where the bolt remains lodged through splashdown, the snubbers would be inhibited from performing their splashdown function, resulting in significant damage to nozzle components. Borescope inspections of nozzle flex bearing cavities were performed on all completed nozzles at KSC, including STS-41. Thiokol will perform a borescope inspection as part of the mandatory preshipment inspection for all future flight nozzles. Rationale for STS-41 flight was: • All known foreign material was removed from STS-41 SRM nozzles. • Any remaining foreign material would be found during a borescope inspection and removed prior to launch. *This risk factor was resolved for STS-41.*

RESOLVED STS-41 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>SRM</u>		
4	Aft dome factory joint internal insulation voids. IFA No. STS-41-M-02 HR No. BC-10 Rev. B-DCN71 {C} ***Abnormal erosion was found at the forward edge of the internal insulation on both SRM aft dome-to-stiffener and stiffener-to-stiffener factory joints on STS-41. Postflight investigation determined that minimum erosion safety factors were exceeded in both areas. (See Section 7, SRM 2 for more details.)***	Aft dome factory joint internal insulation verification has been performed on all aft SRM segments using ultrasonic inspection techniques. On the STS-40 RH aft segment, ultrasonic inspection identified insulation voids. The aft dome factory joint was x-rayed, and 14 voids were discovered. This was the first time that the x-ray inspection technique had been employed to verify insulation integrity. Nine additional SRM aft segments were x-rayed (all motors subsequent to STS-40), and similar internal insulation voids were found. The concern was the effect that voids would have on maintaining the required 2.0 erosion safety factor in the aft dome factory joint insulation. Because of these findings, aft dome factory joints from STS-36 and STS-31 SRMs were dissected. Similar insulation voids were identified. It was determined, however, that these SRMs and others, based on visual postflight inspections, met the erosion safety factor. Postfire insulation samples were taken from all SRMs. These samples had small, entrapped air voids. None of these were considered to be folds, bulges, or thin spots in the insulation. Voids have always been localized and are surrounded by rubber-tearing vulcanized bonds that do not propagate or communicate. Voids are in compression during motor operation. The minimum SRM insulation erosion safety factor over the aft dome joint has been determined to be 3.46 based on postfire evaluation of 400 insulation samples. It is relatively certain that all SRMs have had similar aft dome factory joint insulation voids.

RESOLVED STS-41 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
SRM		
4 (Continued)		The most probable cause of these voids is the insulation layup process. This process has been used on all SRMs to date. Minimum insulation layup was increased from 2.11" to 3.23" for reflight to comply with the increase to a 2.0 erosion FOS. Other factory joints using the same insulation technique have less than 1/2 the required thickness of the aft dome joint. Because the aft dome joint insulation is so thick, it is difficult to avoid entrapping small amounts of air. Rationale for STS-41 flight was: • Postfire evaluations of all SRMs were completed for the aft dome factory joint region with no erosion safety factor violations found (minimum experienced = 3.46). • Based on the process used, STS-41 insulation was concluded to have a safety factor greater than 2.0 over all factory joints. ***This risk factor was acceptable for STS-41.***

RESOLVED STS-41 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>SRM</u>		
5	SRM Ignition Initiator (SII) leak test. HR No. BI-01 Rev. B {C} ***SIIs operated normally on STS-41.***	A postflight anomaly report on STS-31 indicated that grease was found in the leak check hole (10-25 mils in diameter) on the SRM SII. This resulted in general concern regarding the validity of the leak test on the SII during seal installation. The SII is a modified NASA Standard Initiator (NSI) designed with redundant and verifiable seals. The primary O-ring is a shoulder seal (packing). The secondary O-ring is a face seal that seals against the SII weld washer. The SII assembly and inspection criteria include a visual inspection of all seal surfaces in the Barrier-Booster (BB) housing prior to assembly. The O-rings are greased with a thin film before installation. The torque is verified, the SII is lockwired, and leak test is performed. The seal leak test criteria includes a 50-pounds per square inch gage (psig) pressure decay check. The allowable is no more than a 1-psi loss in a 10-min period. Seal use history reveals that no leak test failures have occurred in the Redesigned Solid Rocket Motor (RSRM) motors to date. The current SII and seal configuration has been used since STS-7 (282 samples have demonstrated a theoretical reliability of 99.75%). All have shown no seal violations or seal distress for this configuration. (RSRM postfire inspection has shown no soot past the third thread of the SII or up to the primary seal). Grease has been visually noted at the leak test through hole in several SIIs after disassembly. Joint seal design provides a high confidence that the seals will function properly. Testing showed that the shoulder seals provide reliable sealing at low torques. Tests on initiator pressure port plugs showed that a similar configuration will seal even with anomalous assembly. Tests without the primary seal indicated the secondary seal functioned as designed.

RESOLVED STS-41 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>SRM</u>		
5 (Continued)		Rationale for STS-41 flight was: • STS-41 SIIs, BB seal surfaces, and O-rings met all inspection criteria. • There was a demonstrated SII reliability of 99.75%. ***This risk factor was acceptable for STS-41.***

RESOLVED STS-41 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
PAYLOAD		
1	Ulysses Radioisotope Thermoelectric Generator (RTG) Pressure Relief Device (PRD) fastener failure. ***No anomalies were reported on STS-41.***	During installation of the PRD onto the RTG, 1 of the 4 retaining screws (10-32) seized, and the fastener head snapped off. All of the loose hardware was recovered (fastener head and washer). Attempts to remove the remaining portion of the screw were unsuccessful. A problem associated with the PRD fasteners on STS-34/Galileo resulted in an indepth structural evaluation to clear Galileo for flight. The engineering evaluation was performed using a spare RTG and PRD at the Jet Propulsion Laboratory (JPL) to determine the structural integrity of the fastener. The JPL determination, which was also confirmed by General Electric (GE), was that adequate margin of safety existed to fly "as is" with 3 fasteners. Rationale for STS-41 flight was based upon the analysis previously performed for Galileo (loads and FOS) and was as follows: • The maximum bolt tension produced by 69 g is 42 lb. • The FOS on relief of preload is 21. • The FOS relative to helicoil pullout is 61. • The conservatively estimated acceleration as seen by the PRD is 69 g. • This analysis was applicable for any 1 missing bolt of the 4 bolts. ***This risk factor was resolved for STS-41/Ulysses.***

SECTION 5

STS-31 INFLIGHT ANOMALIES

This section contains a list of Inflight Anomalies (IFAs) arising from the STS-31/OV-103 mission, the previous Space Shuttle flight. Each anomaly is briefly described, and risk acceptance information and rationale are provided.

Hazard Report (HR) numbers associated with each risk factor in this section are listed beneath the anomaly title. Where there is no baselined HR associated with the anomaly, or if the associated HR has been eliminated, none is listed. Hazard closure classification, either Accepted Risk {AR} or Controlled {C}, is included for each HR listed.

SECTION 5 INDEX

STS-31 INFLIGHT ANOMALIES

STS-31 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>ORBITER</u>		
1	Auxiliary Power Unit (APU) #1 speed control failure. IFA No. STS-31-01 HR No. ORBI-031 {AR} ORBI-040 {AR} ***All APUs operated normally on STS-41.***	During the STS-31 launch attempt on April 10, 1990, APU #1 exhibited speed control problems shortly after startup. Indications were that low speed could not be maintained. The crew manually commanded APU #1 to high speed that was successfully maintained. Upon cycling back to low speed, the same erratic behavior occurred. A decision was made to scrub the launch attempt and to plan for an extended turnaround. The APU controller was sent to Sundstrand, the APU vendor, for failure analysis. The analysis indicated that all APU controller functions were nominal. Having cleared the APU controller as the source of the speed control failure, removal and replacement of APU #1 was directed because the Gas Generator Valve Module (GGVM) cannot be removed with the APU installed in the Orbiter. APU failure analysis at Sundstrand confirmed that the problem was in the Pulse Control Valve (PCV); the Shutoff Valve (SOV) was cleared. Sundstrand ran 1900 cycles of the PCV and determined that there was a blowing leak through the valve, indicating a flow path through the valve seat. Failure modes include cracking or chipping of the valve seat. Because the GGVM is sealed, it was sent to Eaton Consolidated Controls, the valve vendor, for further failure analysis. Failure analysis at Eaton included teardown of the GGVM. Teardown revealed missing material from the PCV seat: 0.040" x 0.150" x 0.050". A particle believed to be the missing seat material was found in the valve. Damage to the PCV housing was also noted. The condition which resulted in the loss of valve seat material has not been determined. A record review found that this GGVM was installed on APU #1 prior to STS-26 and had flown on all subsequent OV-103 missions.

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
1 (Continued)		Removal and replacement of the APU was completed on April 17, 1990; a hot-fire test of APU #1 was successfully conducted on April 18, 1990. Post hot-fire inspection of the aft compartment found no problems. Review of recorded data indicated that the APU performed nominally during the hot fire. Problems have been discovered with other APU/GGVMs. See Section 4, Orbiter 3 for further details. Rationale for STS-41 flight was: • A stuck SOV due to smart contamination is extremely unlikely, and overspeed protection should be maintained. • A similar failure prior to liftoff would result in a launch scrub. • A similar failure after liftoff would result in selection of high-speed operation; not desirable, but an acceptable risk. • APUs are redundant in the event one APU should require shutdown. ***This risk factor was acceptable for STS-41.***

STS-31 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
2	Reaction Control System (RCS) thruster L3A anomalies. IFA No. STS-31-3A STS-31-3B HR No. ORBI-056 {C} ***No RCS thruster anomalies were reported on STS-41.***	RCS thruster L3A failed "off" during post-Main Engine Cutoff (MECO), Main Propulsion System (MPS) dump, +X maneuver. This thruster was deselected from further use by Redundancy Management (RM) when the chamber pressure did not reach 36 pounds per square inch absolute (psia) in the 265-millisecond (msec) time period. Initial indications were that the oxidizer injector valve was not open. Approximately 7 hours (hr) after this failure, thruster L3A oxidizer temperature dropped from 90°F to 21°F indicating that the oxidizer injector valve was leaking. It is believed that frozen propellant plugged the thruster throat approximately 45 minutes (min) after oxidizer leak initiation. This was indicated by the increase in chamber pressure to 42 psia. The frozen plug leaked propellant many times, resulting in injector temperature fluctuations. This phenomenon was indicated by the near simultaneous fluctuation of chamber pressure and oxidizer temperature. Manifold #3 isolation valves were closed to isolate further leakage and avoid propellant loss. Oxidizer temperature and chamber pressure continued to oscillate until the frozen propellant blockage melted. These failure modes were similar to thruster anomalies experienced on STS-5, STS-41G, STS-29, and STS-30; however, there was no previous indication of throat blockage. The failure mechanism for the previous anomalies was attributed to nitrate formation/contamination in the oxidizer valve pilot poppet. Initial L3A failure analysis performed at Marquardt, the thruster vendor, confirmed that nitrate contamination in the pilot poppet led to the failed "off" condition. Thruster L3A has had problems since installation on OV-103 in 1988. In January 1988, a helium leak check found a valve leak rate of 450 standard cubic centimeters per minute (sccm) at 250 pounds per square inch gage (psig); the allowable leak

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
2 (Continued)		rate is 350 sccm. This condition was waived prior to STS-26. Post-STS-26 return to Kennedy Space Center (KSC) found nitrogen tetroxide vapors emanating from L3A at a concentration of 25 parts per million (ppm). L3A performance on STS-29 was good with no anomalies. Postflight inspection of L3A at KSC found it was dripping liquid believed to be nitric acid. More dripping liquid was later seen, and inspection found deposits inside the nozzle. During September/October 1989, heavy vapors were witnessed coming from L3A. More dripping liquid was seen in October 1989. In all cases of dripping liquid, the liquid was not analyzed because it was felt that it was nitric acid, the result of hydrazine (thruster fuel) contacting moisture, most likely from the ambient air. Prior to STS-33, manifold #3 was evacuated to service the thruster propellant. Previous failure analysis determined that manifold evacuation leads to drawing of moisture through the thruster valves and results in contamination of valve poppets. Valve contamination is the primary cause of nearly all thruster failures. STS-33 L3A operation was nominal. In December 1989, visible vapors were seen emanating from L3A. Vapor concentrations were deemed borderline nominal; however, visible vapor is a rare occurrence. Failure analysis of L3A at Marquardt, using helium at low pressure, confirmed valve leakage. A computer-enhanced x-ray showed something between the pilot poppet and seat, causing the poppet to be held open approximately 0.004". A force deflection test demonstrated normal mainstage movement, but higher than normal force on the pilot stage. Dragging was also witnessed during closing of the pilot stage. Initial failure analysis found "gelatinous" iron nitrate contamination in the valve assembly. The valve was cut open, revealing gross metallic nitrate deposits around the pilot poppet.

STS-31 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
2 (Continued)		A tiger team was convened to review thruster failures and to formulate recommendations to reduce future problems. One fix already in work is the universal throat plug. The plug has been designed to completely seal the thruster throat from water/moisture intrusion and is considered to be the primary means for eliminating thruster problems. Rationale for flight of RCS thrusters on STS-41 was: • Thrusters have multiple redundancy for nominal mission phases (Crit 1R3) and single redundancy (Crit 1R2) for Return-To-Launch Site (RTLS) contingency. ***This risk factor was acceptable for STS-41.***
3	Supply water tank "C" bellows anomaly. IFA No. STS-31-04 ***No anomaly was reported on STS-41.***	During prelaunch, water tank "D" normally drains into tank "C". On orbit, tanks "C" and "D" failed to equalize quantities per normal operation. It was suspected that the tank "C" bellows was stuck in the fill position. Water was drained from tanks "C" and "D" through Flash Evaporator System (FES) "B" in an attempt to free the stuck bellows. This worked, and the water quantities equalized. Water tank "C" was tested at KSC with no repeat of the on-orbit anomaly. Tank troubleshooting found minor sticking of the bellows at the 100% position.

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>ORBITER</u>		
3 (Continued)		Rationale for STS-41 flight was: • Extensive troubleshooting could not repeat this anomaly; it was closed as unexplained. ***Not a safety concern for STS-41.***
4	Water Spray Boiler (WSB) #2 vent heater "A" did not respond on orbit. IFA No. STS-31-05 HR No. ORBI-170 {C} ***No WSB anomalies were reported on STS-41.***	After operating erratically before launch, WSB #2A heater failed to respond when power was applied on orbit. After attempting to cycle the heater commands, WSB #2B heaters were turned on and functioned properly for the remainder of the STS-31 mission. Previous failures occurred on STS-33, STS-34, and STS-36. WSB controllers are Crit 1R3. There are 2 redundant controllers (A and B) for each boiler. Postflight troubleshooting of WSB #2 heaters and controllers at KSC found tiles in contact with the WSB vent nozzle. Temperature profile tests showed the tiles acting as heat sinks. Tiles in the area of the nozzle were reworked. Rationale for STS-41 flight was: • Tiles in the area of the vent nozzle were shaved. No further problems were expected. • WSB #2 heaters and controllers were checked prior to STS-41. ***Not a safety concern for STS-41.***

STS-31 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>ORBITER</u>		
5	Fuel Cell (FC) #2 Oxygen (O_2) flow rate was high during purge. IFA No. STS-31-06 HR No. ORBI-285 {C} ***All FCs operated normally on STS-41.***	During FC #2 purge operations, the O_2 flow rate was high for approximately 22 seconds (sec), reaching a maximum rate of 12 pounds per hour (lb/hr). O_2 flow returned to normal after this short excursion. A problem with the integrated dual gas regulator was suspected. Resolution of this anomaly and failure analysis required the removal and replacement of FC #2. There were no similar problems experienced to date. This anomaly is detectable by flow meters, coolant pressure, and tank quantities. There is a large voltage margin designed into the FC, and the FC can be saved for entry if necessary. Regulator teardown and inspection at the vendor found minor contamination, but nothing that should cause this failure. The regulator was reassembled and installed in a FC for further testing. Rationale for STS-41 flight was: • FC #2 was replaced. • No similar anomalies were experienced during ground tests. ***Not a safety concern for STS-41.***

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
6	APU #3 fuel pump bypass heater "A" failed on. IFA No. STS-31-08 HR No. ORBI-250 {AR} *All APUs operated normally on STS-41.*	During Flight Control System (FCS) checkout prior to entry, APU #3 fuel pump bypass heater "A" temperature ramped up to approximately 196°F and tripped a fault detection alarm. The system was reconfigured to heater "B", and the bypass temperature returned to the normal range. APU #3 bypass heater "A" operated erratically during STS-33. A decision was made not to replace the thermostat prior to STS-31 because APU #3 was scheduled for replacement after STS-31. This was an expected anomaly. APU #3 has been replaced. Rationale for STS-41 flight was: • This anomaly was expected for STS-31 due to previous occurrences; no corrective action was performed prior to STS-31 launch. • APU #3 had been replaced. *Not a safety concern for STS-41.*
7	Air Data Transducer Assembly (ADTA) #3 circuit breaker contamination. IFA No. STS-36-12 *No anomaly was reported on STS-41.*	During checkout prior to entry, ADTA #3 was bypassed on transition to software mode OPS-8. Indications were that ADTA #3 had no power. The crew cycled the associated circuit breaker 5 times with no success. An additional 5 cycles were required to restore power to ADTA #3. The circuit breaker worked as designed during the remainder of entry preparations. The additional cycles violated Flight Rules and Operational Maintenance Requirements and Specifications Document (OMRSD) requirements that were established to clear possible contamination in circuit breakers. Contamination problems had been experienced several times

STS-31 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
7 (Continued)		during flight and turnaround operations. The circuit breaker was replaced prior to STS-41/OV-103. Contamination was found external to the circuit breaker. Rationale for STS-41 flight was: • Contamination had previously caused similar problems with circuit breakers; repeated cycling usually cleared the contamination. • ADTA #3 circuit breaker was replaced. ***This risk factor was resolved for STS-41.***
8	Missing seal material from trailing edge of elevon flipper doors #5 and #6. IFA No. STS-31-15 HR No. ORBI-003 {C} ***No problems associated with the elevon flipper doors were reported on STS-41.***	Postflight inspection of OV-103 found seal material missing from the trailing edge of Right-Hand (RH) elevon flipper doors #5 and #6. Further inspection found the bulb seal from flipper door #5 in the upper elevon cove area. The ring retainer for flipper door seal #6 was not found. Retainer hardware on flipper doors #5, #6, #12, and #13 were found to be installed backwards. Retainer installation was corrected. Inspection of flipper doors #5 and #6 for heat effects was performed prior to STS-41; none was found. An investigation is underway to determine why retainers were incorrectly installed. The associated job card was modified to include an installation drawing.

STS-31 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
8 (Continued)		Rationale for STS-41 flight was: • Inspection of OV-103 flipper doors was completed with no additional anomalies found. • Retainer installation on flipper doors #5, #6, #12, and #13 was corrected. ***This risk factor was resolved for STS-41.***

STS-31 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
SSME		
1	Engine #2031 High-Pressure Fuel Turbopump (HPFTP) seal fragments. IFA No. STS-31-E-02 HR No. ME-D3 (All Phases) {AR} ***No HPFTP problems were reported on STS-41.***	During postflight inspection of STS-31/OV-103 Main Engine (ME) #2, engine #2031, a scheduled disassembly of HPFTP #6102R1 revealed 2 different sections of the pump-end outboard static seal were missing: 3.3" and 0.7" circumferential lengths, respectively. The HPFTP mount ring static seal has an approximate total circumferential length of 39.9" and is fabricated of Inconel X-750 with gold plating. One piece of the missing seal material, measuring 0.47" long x 0.45" wide x 0.026" deep, was found and removed from joint G3 of the High-Pressure Oxidizer Turbopump (HPOTP). This piece is believed to have migrated to the HPOTP (turbine side) subsequent to engine shutdown (zero-g environment, post-MECO). During pump operation, fragments from the static seal could enter the hot-gas flow. Fragments of the size missing from the HPFTP #6102R1 seal would not affect HPFTP performance and would be of insufficient mass to cause downstream damage. It is postulated, however, that fragments have the potential to migrate to the Liquid Oxygen (LOX) hot-gas manifold in a zero-g environment. This migration could result in damage to the heat exchanger coil when the engine is next started. The scenario needed to result in this damage requires a "smart" particle to strike a turbine blade in such a way as to gain sufficient velocity to impact the heat exchanger. Heat exchanger impact tests showed potential coil punctures with fragment masses greater than 0.06 grams. Of the total seal material missing, 2 pieces were found in the main injector plus the piece found at HPOTP joint G3, accounting for a net mass of 0.25 grams. A net mass of 0.35 grams remained unaccounted for.

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
SSME		
1 (Continued)		Review of static seal test history found 53 cases of outboard seal cracks, with 5 cases where seal segments were missing. These cases were determined from a data base of 83 dual pilot housing builds with a total of 434 starts and 168,638 sec of operation. Missing pieces ranged from 0.5" on HPFTP #2105 with 7 starts and 3432 sec of operation, to 6.0" on HPFTP #4204 with 6 starts and 2323 sec of operation. HPFTP #6102R1 had 6 starts and 3135 sec of operation. Rationale for STS-41 flight was: • All HPFTPs on STS-41 SSMEs were disassembled since the last flight, with no similar seal anomalies noted. ***This risk factor was resolved for STS-41.***

STS-31 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
KSC		
1	MPS Liquid Oxygen (LO_2) outboard fill and drain valve close failure. IFA No. STS-31-K-01 HR No. INTG-085A {C} ***No problems were experienced with the MPS LO_2 fill and drain valve on STS-41.***	During the second launch attempt of STS-31, the ground launch sequencer issued a command at T−48 sec to close the outboard fill and drain valve. This command was not sent to the vehicle because prerequisite control logic was active which verifies that the LO_2 transfer feedline purge valve is closed. The result was a hold at T−31 sec, because confirmation of outboard fill and drain valve closure was not available. This was not a software problem as previously reported. Subsequently, the fill and drain valve was manually commanded closed and was verified by software, and the launch continued. As a result of the power outage experienced during the STS-31 pad testing, it was decided to activate the feedline purge on the LO_2 transfer feedline to prevent any hammer effect if power was lost and the External Tank (ET) had to be drained. This purge was manually activated at approximately T−100 sec. A deviation to S0007 was written and approved to allow manual activation of the purge. However, the fix to the potential power loss problem, approved in the deviation, was not tested prior to the launch attempt. Corrective action was completed for STS-41 to determine an alternative for protecting against hammer effects at loss of power. (See Section 4, Integration 2 for further details.)

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
KSC		
1 (Continued)		Rationale for STS-41 flight was: • Procedures were developed to maintain control in the event of power loss during the terminal sequence. • Mode 1 egress is initiated after the crew sets appropriate switches. • Console operators and STS-41 crew were briefed on this potential scenario. ***This risk factor was acceptable for STS-41.***

SECTION 6

INFLIGHT ANOMALIES FROM PREVIOUS OV-103 FLIGHT

The STS-31 mission was the previous Space Shuttle flight as well as the previous flight of the Orbiter Vehicle (OV-103). The Inflight Anomalies (IFAs) arising from the STS-31/OV-103 mission are presented in Section 5.

SECTION 7

STS-41 INFLIGHT ANOMALIES

This section contains a list of Inflight Anomalies (IFAs) arising from the STS-41/OV-103 mission. Each anomaly is briefly described, and risk acceptance information and rationale are provided.

Hazard Report (HR) numbers associated with each risk factor in this section are listed beneath the anomaly title. Where there is no baselined HR associated with the anomaly, or if the associated HR has been eliminated, none is listed. The Hazard closure classification, either Accepted Risk {AR} or Controlled {C}, is included for each HR listed.

SECTION 7 INDEX

STS-41 INFLIGHT ANOMALIES

STS-41 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
INTEGRATION		
1	System Management (SM2) Nominal Bus Assignment Table (NBAT) General Purpose Computer (GPC) #2 assignment anomaly. IFA No. STS-41-I-01 HR No. ORBI-066 {AR} ORBI-194 {AR}	During performance of STS-41 post-insertion procedures, the crew discovered that GPC #2 had been assigned to string 3 according to SM2 NBAT; GPC #2 should have been unassigned. Investigation determined that this condition existed prior to launch. Further investigation found that an error was made during S0007 troubleshooting of an Inertial Upper Stage (IUS) valve configuration problem. Review of Launch Processing Set (LPS) retrievals found that Data Entry Unit (DEU) equivalent commands were issued on October 5, 1990, to SPEC 0, GPC Memory. DEU equivalent commands should have been sent to SPEC 62, Payload Communications Display, per the IUS telemetry configuration. The resulting NBAT anomaly would not have affected the actual bus assignments, because flight software would not have accepted this configuration. The crew reworked the NBAT to the proper configuration. A review of software change procedures at Kennedy Space Center (KSC) was undertaken to determine if acceptable validation procedures exist. In addition, a review of all potential issuances of DEU equivalent commands by the LPS was completed. It was determined that, in all cases except IUS Telemetry Format Load (TFL) Lockup, all LPS Ground Operations Aerospace Language (GOAL) programs that issue DEU equivalent commands verify proper SPEC prior to releasing the command. Efforts are underway to include the IUS TFL Lockup in the GOAL SPEC verification process prior to DEU equivalent command issuance. Evaluation of software-driven operations at KSC has determined that the potential exposure to similar problems is limited to S0007 operations.

STS-41 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
INTEGRATION		
2	Aft compartment Hydrogen (H_2) concentration high during ascent. IFA No. STS-41-I-03 HR No. ORBI-306 {AR}	Postflight analysis of STS-41 aft compartment catch bottle contents indicated the highest ascent H_2 concentrations of any Shuttle mission. Leak rate calculations based on H_2 concentrations in the STS-41 catch bottles ranged from 25,000 standard cubic inches per minute (scim) to 37,000 scim. Average H_2 leakage during ascent for the fleet is less than 10,000 scim. Prior to STS-41, the maximum catch bottle H_2 concentration was on STS-31, the last OV-103 mission. Leak calculations based on the STS-31 sample resulted in an estimated 30,000-scim leak rate. A leak greater than 59,000 scim, coupled with a sufficient amount of Oxygen (O_2), is considered to be the minimum flammability limit. Through the 11 OV-103 flights, there has been a trend of increasing H_2 concentrations in the catch bottles. Catch bottles are used to periodically sample aft compartment atmosphere for H_2, O_2, and other potentially hazardous elements. Samples are analyzed at KSC using a gas chromatograph. There are 6 catch bottles in each aft compartment, and it is not unusual to have only 1 to 3 good samples. Catch bottle samples with argon present, or catch bottles with higher than expected pressure, are discarded because they indicate atmospheric leakage into the bottles after landing. At present, the cause of the leakage is unknown, and there were no indications of any leakage prior to launch. A possible leak source is the Space Shuttle Main Engines (SSMEs). Prior to engine start, only approximately 5% of the SSME H_2 joints are wetted. The 3 SSMEs on STS-41 have been on OV-103 for 3 flights, and all will be removed. Because of the potential for leakage, special tests, including bagging each SSME individually, will be performed. Additionally, all Main Propulsion System (MPS) and SSME interface joints will be leak checked prior to SSME removal.

STS-41 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
INTEGRATION		
3	Left-Hand (LH) Solid Rocket Booster (SRB) aft strut separation device NASA Standard Initiator (NSI) detonator separated from the pressure cartridge. IFA No.STS-41-I-04 HR No. INTG-135 {C}	Postflight inspection of STS-41 Solid Rocket Motors (SRMs) found that NSI, lot number MPX, Serial Number (S/N) 1193, had been ejected from the pressure cartridge, Part Number (P/N) 10303-0001-801, lot number AAP, S/N 2,003,371. This ejection occurred after the proper functioning of the NSI during SRB/External Tank (ET) aft strut separation. The resulting debris was contained by the surrounding foam insulation, and there is no debris concern raised by this anomaly. This was the first occurrence of this failure mode in flight; several failures of this type were experienced during SRB/ET aft strut separation device qualification tests (in excess of 74% of the 35 devices tested). It is therefore believed that this type of failure was expected to occur during flight during the life of the program. In all cases, this was a post-function failure of the NSI in the aft strut separation device; in no case did the separation device fail to separate. Orbiter separation hardware and other NSI applications have had no history of NSI ejections, either during qualification testing or flight. NSI applications in SRM Igniter Initiators (SIIs) have had no similar ejection problems either in qualification tests or flight. Initial hardness measurements taken on NSI S/N 1193 at United Space Boosters, Inc. (USBI) indicated that it was below the minimum Rockwell hardness of 36. Subsequent hardness measurements of S/N 1193 at Rockwell determined that the actual hardness was in excess of the requirement. Original coupon hardness data for lot MPX also indicated hardness measurements in excess of the requirement. The USBI measurements, therefore, were determined to be in error.

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>INTEGRATION</u>		
3 (Continued)		Each NSI is subjected to proof-pressure testing at 15,000 pounds per square inch gage (psig) prior to propellant loading during fabrication. Proof-pressure tests of 2% of each lot subjects NSIs to 40,000 pounds per square inch (psi). Independent testing at Marshall Space Flight Center (MSFC) has demonstrated that the NSI will rupture at the thread relief when subjected to hydrostatic pressure of 66,000 psi. The resulting safety margin, based on NSI static test pressures, is greater than 4.

C-2

STS-41 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
1	Auxiliary Power Unit (APU) Gas Generator (GG)/Fuel Pump (FP) heater system "B" failed "on" during STS-41. IFA No.STS-41-03 HR No. ORBI-104A {C}	During Flight Day (FD) 4 checkout of the Flight Control System (FCS), normal switchover of the APU heaters from system "A" to "B" was performed. Upon switchover, the "B" heater failed to cycle off. APU heater cycling is thermostatically controlled, cycling on at 73°F and off at 100°F. A Fault Detection and Annunciator (FDA) alert sounded when the temperature in the APU fuel bypass line reached 180°F. This occurred 2 minutes (min) after switchover from system "A" to system "B" heaters. The bypass line temperature rose at a rate of 40°F/min versus the 6°F/min nominal rate. APU fuel bypass line temperatures peaked at 258°F approximately 3 min following switchover. The crew immediately switched back to the system "A" heaters, and normal GG/FP heater cycling resumed. This failure mode was indicative of a short in the heater string with possible thermostat failure. The worst case would be a failed "on" heater. If the failed "on" heater is not detected, the fuel lines would overheat (Crit 1R/2). Hydrazine would detonate at 350°F and result in APU fuel line rupture, hydrazine leakage, fire, and potential loss of crew and vehicle. Cycling APU GG/FP heaters off at 100°F is designed to protect against fuel line overtemperature. Troubleshooting at KSC found a short circuit to ground between the fuel line heater and the water valve heater wires. This short is believed to be at a location where a clamp is used to secure the wiring to the fuel line. Further troubleshooting is in work to isolate the short. Activity associated with changeout of the system "A" thermostat during STS-41 flow processing is believed to have caused the damage to the system "B" wiring. Both system "A" and "B" wiring run through the same cable.

STS-41 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
1 (Continued)		Retest of system "A" was performed after the thermostat changeout with no anomalies noted; however, no tests were performed on system "B". As a result of follow-up actions taken at the subsequent STS-38 Flight Readiness Review (FRR), the following functional changes are being effected to mitigate/reduce the risk associated with a potential "smart" APU heater circuit failure on orbit, as was experienced on STS-41. • Prelaunch tests will be conducted during tanking for flight on all APU heaters. This test will include switching between "A" and "B" heaters. • There will be a new APU high-temperature FDA limit set at 150°F. The current limit is 180°F. This will provide an additional minute of response time to the crew. To enhance response awareness, the ground monitoring system has been changed to alert the APU console operator when temperatures reach 130°F. • All APU reconfigurations will be performed in Acquisition of Signal (AOS) conditions only to allow ground monitoring of any failure. • On FD 1, heater reconfiguration will be performed early, at 6-hour (hr) Mission Elapsed Time (MET), to allow verification of system "B" heaters. • Any APU heater anomalies detected during AOS conditions will result in the crew powering down all APU GG/FP heaters. Heater reconfiguration will follow for the failed heater, and the remaining heater strings will be reactivated.

STS-41 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
1 (Continued)		• To enhance response time, "booties" will be installed on APU heater switches for quick recognition. Additionally, the crews' orbit pocket checklist is being updated to reflect crew response procedures in the event of an APU heater FDA.
2	Inertial Measurement Unit (IMU) #1 experienced Z-axis accelerometer transients. IFA No. STS-41-04 HR No. ORBI-051 {C}	IMU #1, S/N 007, was deselected by Redundancy Management (RM) because it was experiencing Z-axis accelerometer shifts of up to 10,000 micro-g's. The problem occurred several times, with the transient lasting from 5 to 15 min at a time. IMU #1 did, however, track the redundant IMU set following deselection. A similar problem was experienced on STS-32, when IMU #1, S/N 024, was deselected for Y-axis transients. There was no indication that this is a generic IMU problem; however, there have been 2 flight and ground-based test transient accelerometer failures. IMU #1, S/N 007, will be removed and replaced at KSC. The concern with an IMU failure is that first or second failures may require crew action to downmode IMUs to standby if in OPS-2 or OPS-3, or to downmode to off in all OPS modes if IMUs are clearly degraded beyond use. This could result in possible crew/vehicle loss due to multiple-axis second failure. If the second failure is multiple axis, it could be detected but not isolated. There is a possibility of RM prime selecting the failed IMU; the crew would be required to select the good IMU if it can be determined from ground track information that the failed IMU had been selected by RM prime. Failure of the navigation base could result in loss of all 3 IMUs, which would result in loss of crew and vehicle.

STS-41 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>ORBITER</u>		
3	Backup Flight Software (BFS) backup cabin delta-pressure/delta-temperature alarm was triggered at Main Engine Cutoff (MECO). IFA No. STS-41-05	The BFS backup delta-pressure/delta-temperature calculation at MECO indicated a cabin pressure leak rate in excess of 0.14 psi/min. This calculation generated an alarm to the crew to identify the apparent condition. After silencing the alarm and checking alternate readouts, it was determined that there was no cabin leak. Preliminary failure analysis and data review found no problem with either the cabin pressure sensor or the BFS. An actual hardware or software failure would have been detected by ground monitoring. This was the first failure occurrence of this type; there were no other delta-pressure alarms generated for the remainder of the flight. Continued evaluation determined that a 2 data bit step response by the new transducer in the cabin pressure sensor caused the delta-pressure calculation to trigger the alarm. Transducers previously used in the cabin pressure sensor only generated a 1 data bit response. The BFS design group is reviewing this anomaly for a potential software change.
4	STS-41 Commander's Left-Hand (LH) Attitude Direction Indicator (ADI) rate scale switch failure. IFA No. STS-41-06	During FD 4 deorbit preparations, a failure message was presented that identified that the Commanders LH ADI rate scale switch showed both "HI" and "MED" simultaneously. Postflight data analysis confirmed that both signals were active simultaneously for 26 seconds (sec). There have been no prior failures of this switch type without switch operation. This failure mode could not be reproduced during troubleshooting and examination at KSC. The switch will be removed and sent to the vendor for x-ray analysis.

STS-41 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
4 (Continued)		The switch, P/N ME452-0102-7101, is a single-contact, triple-pole, hermetically-sealed toggle switch. This switch has a Criticality (Crit) 3/3 assessment in the ADI circuitry. Rockwell International (RI) identified 196 similar type switches (7106) at other locations in the Orbiter. Two applications are Crit 1R/2, and two applications are Crit 1R3. There were no Crit 1/1 applications identified in the Orbiter.
5	Orbiter/ET Liquid Hydrogen (LH_2) aft attach/separation hole plugger failed. IFA No. STS-41-07 HR No. ORBI-302A {AR}	The Orbiter/ET LH_2 aft attach/separation hole plugger failed to fully close. Postlanding inspection found that the debris plugger in the EO-2 LH_2 separation debris container was caught by the frangible nut halves and failed to seat properly. Three pieces of spent ordnance assembly found on the runway beneath the LH_2 ET/Orbiter umbilical opening may be attributed to this failure. This debris apparently escaped from the debris container after the ET umbilical door closed on orbit. Similar hole plugger failures occurred on STS-29 and STS-34. There was concern that loose debris could block the ET umbilical door from fully closing, resulting in potential loss of the crew and vehicle during reentry. The probability of escaping fragments preventing the ET umbilical door from closing has been determined to be very small. The Orbiter performs a maneuver at ET separation, moving away from the ET and possible escaping debris prior to ET umbilical door closure.

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
6	STS-41 LH Rotational Hand Controller (RHC) trim inhibit switch indicated a contact miscompare. IFA No. STS-41-08	During FD 4 operations, a failure flag indicated that the LH RHC trim inhibit switch "ENABLE" and "INHIBIT" contacts were simultaneously made. Data review confirmed that both signals were present for a 15-sec period. The problem disappeared after this 15-sec period and did not repeat. The RHC trim inhibit switch, P/N ME452-0102-7201, is a Crit 3/3 application. This anomaly could not be repeated during troubleshooting at KSC (unexplained anomaly). There are a total of 274 P/N ME452-0102-7201 switches per Orbiter. Two applications (CRT SEL Switch #7 and #8) are located in the Data Processing Software System (DPS) and have been identified as Crit 1/1. Switch #7, the left-side CRT SEL switch, provides the means for switching the left keyboard from the left Cathode Ray Tube (CRT) to the center CRT or vice-versa. Switch #8, the right-side CRT SEL switch, provides the means for switching the right keyboard from the right CRT to the center CRT or vice-versa. During a Crit 1/1 failure mode (fails closed, premature closed, or contact-to-contact short), both the center and either the left or right Display Electronic Units (DEUs) will respond to the same keyboard entry due to switch failure. If this were to occur in a critical situation, the results could be catastrophic. However, the Redundancy Management System (RMS) would recognize the opposing commands, vote out the input, and disregard the entry. For this application, actions taken by the RMS are not considered as a backup to switch failure. There have been 3 previous failures of this switch type in different applications: 1 failure in flight on a flight deck speaker microphone unit, and 2 failures during testing at the Shuttle Avionics Integration Laboratory (SAIL). Of the 3 previous recorded failures, only 1 was considered to be a hardware failure and was attributed

STS-41 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
6 (Continued)		to wear. The switch had been operated in excess of its certified life. Flight and test history data indicate that there have been no failures related to age or number of cycles within the qualified lifetime. Ground turnaround test, including keyboard testing, verifies that all Crit 1/1 and 1/R2 switches are functional.

STS-41 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>SRM</u>		
1	SRM igniter outer joint putty blowholes with cadmium plating damage and sooting. IFA No. STS-41-M-01 HR No. BC-02 Rev. B {AR} BC-03 Rev. B {C} BI-02 Rev. B {C}	Blowholes were found during disassembly of STS-41 SRMs. The blowholes, and resulting sooting and damage to the seal retainer cadmium plating, were similar to that seen on previous flight SRMs and test motors. (See Section 4, SRM 2 and SRM 3 for details of previous experience.) A single blowhole in the outer joint putty was located at the 165° position on the LH SRM . The blowhole measured 0.25" at the start, and widened to 0.5" before contracting to 0.2" at the gasket face. This condition was similar to blowholes experienced on STS-36 (IFA No. STS-36-M-01). The significance of this occurrence was the cadmium plating damage on the outer Gask-O-Seal in an arc from 171° to 162° in line with the blowhole. Most of the cadmium plating was missing up to the cushion material, and small amounts of cadmium were folded up over the edge of the cushion. On the aft seal face, cadmium was missing from the retainer in the 92° to 108° area; the damage was not as severe as on the forward face. However, there was no evidence of cadmium melting (610°F melting point) at the edge of the remaining cadmium. Pitting was observed at various locations on the adapter, with a maximum depth of 0.0015" at 165° which corresponds to the location of the blowhole. Soot was observed to the primary seal in the 126° to 171° area on the forward face. Light-to-intermittent corrosion was found 2.5" inboard of the adapter outer diameter for the full circumference. Residue on the gasket retainer was cadmium chloride and combustion products from propellant, putty, and grease. The igniter boss insulation was in good condition with normal charring and erosion. Igniter boss insulation char and erosion thickness measurements were taken at Zone A and at the adapter 6.0" radial station. The 0.010" virgin insulation thickness requirement for Zone A was met, with the minimum thickness being 0.148". The 1.5 thermal safety factor requirement for the igniter was met; the lowest calculated safety factor was 3.19. No edge unbonds were found.

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
SRM		
1 (Continued)		A blowhole in the outer joint putty was found at the 268° position on the Right-Hand (RH) SRM . The blowhole measured 1.3" at the start and was 0.25" at the through point. Soot was observed on the forward face to the primary cushion through 262° to 270°. There was soot on the full circumference of the gasket and on the aft face of the metal retainer through the arc 171°-0°-45°. There was no evidence of soot past the primary seal. Light heat effects to the cadmium was found from 262° to 270°. Light corrosion was present on the aft face and the inside diameter at 270°. The condition of the inner joint putty/insulation and chamber insulation was normal. Chamber insulation char and erosion measurements were taken at Zone A. The 0.010" virgin insulation thickness requirement was met; the minimum thickness was 0.070". The 1.5 thermal safety factor requirement for the igniter was met; the lowest calculated thermal safety factor was 3.69. Both outer Gask-O-Seals were sent to the vendor for evaluation. This evaluation was centered on the potential for detrimental heat effects resulting from erosion of the cadmium plating. Cadmium adjacent to the seal did not melt and was, therefore, below 610°F; the seal is not affected below 805°F. No evidence of heat effects was found on either Gask-O-Seal elastomer. Worst-case thermal analysis predicted no adverse elastomer damage due to blowhole heat effects. The increase in putty blowhole occurrences is believed to be related to the reduction in putty layup in the case-to-adapter joint. This reduction was directed to reduce the likelihood of putty extruding onto the joint sealing surfaces.

STS-41 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>SRM</u>		
2	Abnormal erosion on SRM aft segment factory joint internal insulation. IFA No. STS-41-M-02 HR No. BC-10 Rev. B-DCN71 {C}	Abnormal erosion at the forward edge of the internal insulation was observed on both SRM aft dome-to-stiffener and stiffener-to-stiffener factory joints. The erosion was most evident at the areas of ply overlap. Erosion was random over the full circumference of the aft dome-to-stiffener factory joints and was found at only 4 to 6 locations on the stiffener-to-stiffener factory joints. The remainder of the internal case insulation was in very good condition, with no indication of unusual erosion or indication of hot-gas passage through the insulation. Measurements will be made to determine the thickness of the remaining insulation. These measurements were used to calculate the resulting safety factor. Within 5" of the inner clevis tip, the required safety factor is 2.0; the minimum calculated safety factor for STS-41 was 2.25. Beyond 5", the requirement is a safety factor of 1.5; the mininimum calculated safety factor for STS-41 was 1.57.

SECTION 8

BACKGROUND INFORMATION

This section contains pertinent background information on the safety risk factors and anomalies addressed in Sections 3 through 7. It is intended as a supplement to provide more detailed data if required. This section is available upon request.

The following letter is the launch approval for the Ulysses mission issued on September 21, 1990, by the Executive Office of the President, Office of Science and Technology Policy.

APPENDIX A

LIST OF ACRONYMS

a.m.	Before Noon (Ante Meridiem)
ADI	Attitude Direction Indicator
ADTA	Air Data Transducer Assembly
AFB	Air Force Base
AMOS	Air Force Maui Optical Site
AOA	Abort-Once-Around
AOS	Acquisition of Signal
APU	Auxiliary Power Unit
AR	Accepted Risk
ATN	Advanced TIROS-N
ATP	Acceptance Test Procedure
BB	Barrier-Booster
BFS	Backup Flight Software
	Backup Flight System
BSR	Bite Status Register
C	Controlled
CA	California
CCTV	Closed Circuit Television
CHROMEX	Chromosome and Plant Cell Division in Space
CRES	Corrosion Resistant Steel
Crit	Criticality
CRT	Cathode Ray Tube
DEU	Data Entry Unit
	Display Electronic Units
DPS	Data Processing Software System
EDT	Eastern Daylight Time
EIU	Engine Interface Unit
ESA	European Space Agency
ET	External Tank
F	Fahrenheit
FASCOS	Flight Acceleration Safety Cutoff System
FC	Fuel Cell

APPENDIX A

LIST OF ACRONYMS - CONTINUED

FCL	Freon Coolant Loop
FCS	Flight Control System
FCV	Flow Control Valve
FD	Flight Day
FDA	Fault Detection and Annunciator
FES	Flash Evaporator System
FJPS	Field Joint Protection System
FMEA/CIL	Failure Modes and Effects Analysis/Critical Items List
FOS	Factor of Safety
FP	Fuel Pump
fps	feet per second
FRR	Flight Readiness Review
GE	General Electric
GG	Gas Generator
GGVM	Gas Generator Valve Module
GH_2	Gaseous Hydrogen
GO_2	Gaseous Oxygen
GOAL	Ground Operations Aerospace Language
GOX	Gaseous Oxygen
GPC	General Purpose Computer
GSE	Ground Support Equipment
H_2	Hydrogen
HDP	Holddown Post
HGDS	Hazardous Gas Detection System
HPFTP	High-Pressure Fuel Turbopump
HPOTP	High-Pressure Oxidizer Turbopump
HR	Hazard Reports
hr	Hour
ID	Inside Diameter
IFA	Inflight Anomaly
IMU	Inertial Measurement Unit
in-lb	Inch-Pound
INTG	Integration
IPMP	Investigation into Polymer Membrane Processing
ISAC	Intelsat Solar Array Coupon
IUS	Inertial Upper Stage
JPL	Jet Propulsion Laboratory
JSC	Johnson Space Center

APPENDIX A

LIST OF ACRONYMS - CONTINUED

Kbit	Kilobit
KSC	Kennedy Space Center
L-2	Launch Minus 2 Days (Review)
lb	Pound
lb/hr	Pounds Per Hour
LCC	Launch Commit Criteria
LD	Leak Detector
LH	Left-Hand
LH_2	Liquid Hydrogen
LO_2	Liquid Oxygen
LOX	Liquid Oxygen
LPFTP	Low-Pressure Fuel Turbopump
LPOTP	Low-Pressure Oxidizer Turbopump
LPS	Launch Process Sequencer
	Launch Processing Set
LSFR	Launch Site Flow Review
MCC	Main Combustion Chamber
	Mission Control Center
ME	Main Engine
MECO	Main Engine Cutoff
MEOP	Maximum Expected Operating Pressure
MET	Mission Elapsed Time
MHz	Megahertz
min	Minute
MLP	Mobile Launch Platform
MMT	Mission Management Team
MPS	Main Propulsion System
MSE	Mission Safety Evaluation
msec	millisecond
MSFC	Marshall Space Flight Center
N_2	Nitrogen
NASA	National Aeronautics and Space Administration
NBAT	Nominal Bus Assignment Table
NM	Nautical Mile
NSI	NASA Standard Initiator
NSRS	NASA Safety Reporting System

APPENDIX A

LIST OF ACRONYMS - CONTINUED

O_2	Oxygen
OMRSD	Operational Maintenance Requirements and Specifications Document
OMS	Orbital Maneuvering System
OPF	Orbiter Processing Facility
OPO	Orbiter Project Office
ORBI	Orbiter
OSMQ	Office of Safety and Mission Quality
OD	Outside Diameter
OV	Orbiter Vehicle
p.m.	Afternoon (Post Meridiem)
P/N	Part Number
PAM	Payload Assist Module
PAR	Prelaunch Assessment Review
PASS	Primary Avionics Software System
PCV	Pulse Control Valve
PLBD	Payload Bay Door
POR	Power-On Reset
ppm	Parts Per Million
PRCB	Program Requirements Control Board
PRCBD	Program Requirements Control Board Document
PRD	Pressure Relief Device
PSE	Physiological System Experiment
psi	Pounds Per Square Inch
psia	Pounds Per Square Inch Absolute
psig	Pounds Per Square Inch Gage
QD	Quick Disconnect
RCN	Requirements Change Notice
RCS	Reaction Control System
RH	Right-Hand
RHC	Rotational Hand Controller
RI	Rockwell International
RM	Redundancy Management
RME	Radiation Monitoring Equipment
RMS	Redundancy Management System
	Remote Manipulator System
rpm	Revolutions Per Minute
RSRM	Redesigned Solid Rocket Motor
RTG	Radioisotope Thermoelectric Generator
RTLS	Return-to-Launch Site

APPENDIX A

LIST OF ACRONYMS - CONTINUED

S/N	Serial Number
SAIL	Shuttle Avionics Integration Laboratory
sccm	Standard Cubic Centimeters Per Minute
sccs	Standard Cubic Centimeters Per Second
scim	standard cubic inches per minute
sec	Second
SEM	Scanning Electron Microscope
SII	Solid Rocket Motor Igniter Initators
	Solid Rocket Motor Ignition Initiator
SM2	System Management
SOV	Shutoff Valve
SRB	Solid Rocket Booster
SRM	Solid Rocket Motor
SSBUV	Shuttle Solar Backscatter Ultraviolet Experiment
SSCE	Solid Surface Combustion Experiment
SSME	Space Shuttle Main Engine
SSRP	System Safety Review Panel
TAL	Transatlantic Abort Landing
TEM	Test Evaluation Motor
TFL	Telemetry Format Load
TSM	Tail Service Mast
TVC	Thrust Vector Control
USBI	United Space Boosters, Inc.
VAB	Vehicle Assembly Building
VCS	Voice Command System
WSB	Water Spray Boiler